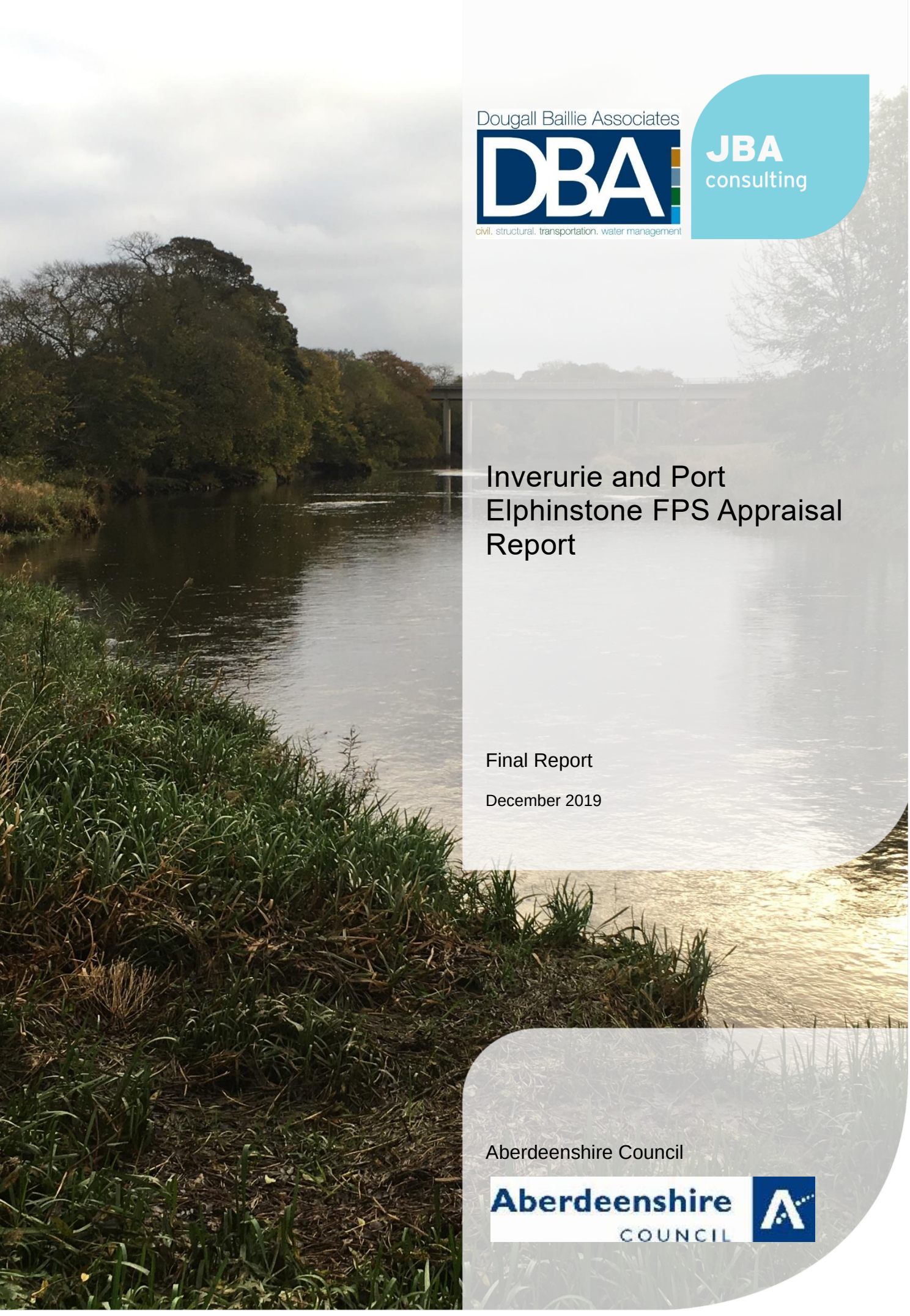

Inverurie and Port Elphinstone FPS Appraisal Report

Final Report

December 2019

Aberdeenshire Council

JBA Project Manager

Caroline Anderton BSc MSc CEnv CSci MCIWEM C.WEM
Unit 2.1 Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision History

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Contract

This report describes work commissioned by Gavin Penman, on behalf of Aberdeenshire Council, on 10 October 2017 by Purchase Order Number 1095192. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Alistair Scotland. Douglas Scoular of JBA Consulting carried out this work.

Prepared by ..... Douglas Scoular MEng
Graduate Engineer

Reviewed by ..... Caroline Anderton BSc MSc CEnv CSci MCIWEM C.WEM
Technical Director

Purpose

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Acknowledgements

JBA wishes to thank SEPA for provision of the hydrometric data and Aberdeenshire Council for the supply of data.

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Inverurie and Port Elphinstone FRM Business Case

Context

Inverurie and Port Elphinstone located in Aberdeenshire have an extensive history of property flooding. JBA was commissioned in 2017 to carry out a review of past 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 communities of Inverurie and Port Elphinstone.

This report focusses on fluvial flood risk from both the River Urie and the River Don.

A modelling exercise was carried out to estimate river levels on the above mentioned watercourses from Old Rayne to the confluence between the Don and Urie on the River Urie and from upstream Haughton to downstream of Kintore on the River Don. A range of possible flood events were modelled from the 50% AP (2 year) event to the 0.1% AP (1000 year) event. Increases to the flow by 24% due to predicted climate change was included to the 0.5% AP (200 year) event.

It was found that 116 properties are at risk of flooding from the 0.5% AP (200 year) event and 138 are at risk for the same event with a climate change allowance. A range of flood protection options were then reviewed and short listed based on their viability.

Risk metrics

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

Residential properties at risk	88 at the 200 year flood (106 with climate change)
Non-residential properties at risk	28 at the 200 year flood (32 with climate change)
Key receptors at risk	Properties along Riverside Park, Keithhall Road, Canal View and Leslie Place

Flood Mitigation Options

Due to more than one watercourse being investigated, Inverurie and Port Elphinstone were split into two different areas and reviewed based on the different mechanisms of flooding:

- Area A (Oldmeldrum Road) - Flood risk from River Urie due to flow over Oldmeldrum Road on the floodplain.
- Area B (Port Elphinstone and South Inverurie) - Flood risk both River Urie and River Don to Port Elphinstone and South Inverurie.

A range of flood protection options were then reviewed and short listed for each area based on their viability. A range of different combinations of options were then put forward as a viable solution for the communities of Inverurie and Port Elphinstone as follows, where the key change between the options is the difference in standard of protection:

- Option 1 (Area A and Area B standard of protection 0.5% AP (200 year) plus climate change):
    - Area A - direct defences upstream of Oldmeldrum Road
    - Area B - direct defences, flood gate, canal foot bridge downstream of rail bridge and weir removal
- Option 2 (Area A and Area B standard of protection 0.5% AP (200 year)):
    - Area A - direct defences upstream of Oldmeldrum Road
    - Area B - direct defences, flood gate, canal foot bridge downstream of rail bridge and weir removal
- Option 3 (standard of protection 3.33% (30 year) at Area A, 0.5% AP (200 year) at Area B):

- Area A - undefended
- Area B - direct defences, flood gate, canal foot bridge downstream of rail bridge and weir removal

- Option 4 (standard of protection 3.33% (30 year) at Area A, 1% AP (100 year) at Area B):
  - Area A - undefended
  - Area B - direct defences, flood gate, canal foot bridge downstream of rail bridge and weir removal

- Option 5 (Area A and Area B standard of protection 0.5% (200 year), 0.1% AP (1000 year) at Kirkwood):
  - Area A - direct defences upstream of Oldmeldrum Road
  - Area B - direct defences, flood gate and canal foot bridge downstream of rail bridge removal

- Option 5b (Area A and Area B standard of protection 0.5% (200 year) plus climate change, 0.1% AP (1000 year) at Kirkwood):
  - Area A - direct defences upstream of Oldmeldrum Road
  - Area B - direct defences, flood gate and canal foot bridge downstream of rail bridge removal

- Option 6* (Area A and Area B standard of protection 0.5% AP (200 year), SW WWTW unprotected):
  - Area A - direct defences upstream of Oldmeldrum Road
  - Area B - direct defences on existing alignment, flood gate and canal foot bridge downstream of rail bridge removal

- Option 6b* (Area A and Area B standard of protection 0.5% AP (200 year), SW WWTW unprotected):
  - Area A - direct defences upstream of Oldmeldrum Road
  - Area B - offset direct defences, flood gate and canal foot bridge downstream of rail bridge

*Option requires further investigation if during the 100 year appraisal period the western Scottish Water site is abandoned. It makes assumptions such as the abandonment of the Scottish Water wastewater treatment works west of the railway line and reuse of the existing embankment soil.

Improving public awareness and resilience

In addition to these short-listed options a number of non-structural options and good practice FRM measures have been investigated and recommended for implementation by Aberdeenshire Council. Some of these could be implemented either in the short term or alongside a Flood Protection Scheme. These include the following:

- Continued maintenance of the flood warning scheme currently in place.
- Community engagement should be continued to raise awareness of flood risk and potential short-term and longer-term solutions.
- Resilient Communities sandbag stores are available in Inverurie and Port Elphinstone. The Council should investigate if an additional store needs to be provided. The Council should also 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. 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 Inverurie and Port Elphinstone.

Expected benefits

A flood damage assessment has been undertaken for the present-day Do Nothing and Do Minimum scenarios and each of the above options. The Present Value flood damages calculated for the Do Nothing and Do Minimum scenarios are estimated to be £13.4 m and £10.6 m, respectively. The damages avoided for each option are in the range of £9.3 m - £12.7 m. Total damages avoided for each option are provided in the investment appraisal summary table below.

Damages avoided:

	Option 1	Option 2	Option 3	Option 4
Standard of Protection (SOP) (years)	200 + climate change	200	Area A - 30 Area B - 200	Area A - 30 Area B - 100
Damages avoided (£k)	10,956	9,359	9,318	9,318

	Option 5	Option 5b	Option 6	Option 6b
Standard of Protection (SOP) (years)	200 Kirkwood 1000	200 + climate change Kirkwood 1000	200 Kirkwood 1000	200 Kirkwood 1000
Damages avoided (£k)	12,112	12,724	12,188	12,187

Working with natural processes

Natural Flood Management (NFM) is a method whereby wider catchment benefits could be achieved alongside potential reduction to flood flows within Inverurie. 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 landowners 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, environmental and land management benefits.

Costs

Costs for each option have been estimated using the Environment Agency's Long Term Costing tool (2012). An optimism bias factor of 60 % has been added to the total costs to allow for uncertainties in design at this stage and is typical for schemes at an early stage of appraisal. Whole life present value costs range from £6.5 m to £11.8 m. Total costs for each option are provided in the investment appraisal summary table.

Investment appraisal

The investment appraisal is provided below. The options show that lowering the standard of protection to be exclusive of climate change gives a far more achievable cost-benefit ratio.

	Do Nothing	Do Min	Option 1	Option 2	Option 3	Option 4
SoP (years)	2	10	200 + CC	200	A - 30 B - 200	A - 30 B - 100
Total PV Costs (£k)	-	-	11,836	9,984	8,843	7,656
PV damage (£k)	13,421	10,557	2,465	4,062	4,103	4,103
PV damage avoided (£k)	-	2,865	10,956	9,359	9,318	9,318
Net present value (£k)	-	2,865	-880	-624	476	1,662
Benefit-cost ratio	-	-	0.93	0.94	1.05	1.22

	Do Nothing	Do Min	Option 5	Option 5b	Option 6*	Option 6b*
SoP (years)	2	10	A - 200 Kirkwood 1000	A - 200 + CC Kirkwood 1000	A - 200 Kirkwood 1000	A - 200 Kirkwood 1000
Total PV Costs (£k)	-	-	9,465	11,332	6,503	7,985
PV damage (£k)	13,421	10,557	1,309	697	1,234	1,234
PV damage avoided (£k)	-	2,865	12,112	12,724	12,188	12,188
Net present value (£k)	-	2,865	2,647	1,392	5,685	4,203
Benefit-cost ratio	-	-	1.28	1.12	1.87	1.53

*Option requires further investigation if during the 100 year appraisal period the western Scottish Water site is abandoned. It makes assumptions such as the abandonment of the Scottish Water wastewater treatment works west of the railway line and reuse of the existing embankment soil.

Residual risks and planning for future flooding

The residual risk in Inverurie and Port Elphinstone is substantial where the above shows that residual risk is a key factor to achieving a positive benefit cost ratio. This is due to properties already having a high SoP where damages start to become extremely large in the later events, particularly the 0.1% AP (1000year) and infinity year which are included in 100 year appraisal period with very low probabilities. The damages are large which results in low probabilities not cancelling out high residual risk as per usual, key beneficiaries to this residual risk are non-residential properties which tend to incur large damages such as the Old Mill at Kirkwood Commercial Park and the industries alongside Keithhall Road. The only solutions to minimise residual risk and ensure sustainability of the flood scheme is to either protect all properties to a minimum of 0.5% AP (200 year) plus climate change; though this incurs large costs, or to raise the standard of protection of the Old Mill at Kirkwood Commercial Park to the 0.1% AP (1000 year) event while still raising the SoP of the rest of the areas to 0.5% AP (200 year) plus climate change.

Conclusions and recommendations

As discussed, achieving a viable benefit cost ratio is challenging within Inverurie and Port Elphinstone due to high costs from the requirement of large lengths of direct defences as well as high residual damages due to extremely large damages during the low probability events.

Option 5b would be the preferred option as it provides the most sustainable solution with the least amount of residual risk, achieving a SoP of 0.5% AP (200 year) with the inclusion of climate change as well as a positive BCR of 1.12. It also includes additional benefits such as improving RBMP by further offsetting the existing embankments as well as social opportunities of formalising floodplain green space and making the canal walkways safer. Options 3 and 4 should not be taken forward, though they do achieve a positive BCR, as they would not be acceptable from the perspective of the larger community as they exclude selected properties (Area A) from a reasonable standard of protection; > 3.33% AP (30 year).

If the current BCR of option 5 is not deemed large enough a future consideration has been made in Option 6 and Option 6b. The Scottish Water wastewater treatment works has been redeveloped to the east of the railway. Over the full 100 year appraisal period there is the potential option for the older site (to the west of the railway) to be demolished, completing relocation of the area. Option 6b shows how relocating this area can achieve a high BCR (1.53) due to the reduction in embankment size, while further increasing the River Don floodplain though this option also relies on the reuse of the existing embankment soil. Both reuse of the existing embankment soil and allowing the Don to flood on this site are future options which are recommended for investigation if Option 5b were not to go forward and within the 100 year appraisal period the western waste water treatment works were to be abandoned.

The matrix overleaf gives an overview of the consideration of each option against different key criteria, as discussed before the key change between the options is the change in standard of protection.

Option	Minimum Standard of protection	Properties protected from 0.5% AP (200 year) plus CC	Environmental implications	Working with natural processes	Constraints/ limitations	Mitigating residual risks	Improved public awareness	Best use of public money	Wider benefits
Option 1 – Area A direct defences Area B direct defences, flood gate, canal bridge and weir removal.	0.5% AP – 200 year plus CC	All properties protected.	Environmental benefit from formalisation of green space Minor disturbance during construction.	RBMP benefit of reconnection to a more naturalised floodplain by setting back existing embankments. Minor amounts of further channel constriction from additional direct defences, mainly during high flooding events. (>100 year)	High direct defences required for a long extent. Modifications to privately owned canal.	High residual damages due to large costs during the low probability events. Consideration of future adaptation to direct defences may be required.	Recommendations of continued work with action groups and the community. Ensure there is a good knowledge of the flood warning scheme that is already in place.	Not cost effective due to expense of defences and high residual risk, benefit cost ratio of 0.93.	Minimal impacts on community other than aesthetics from direct defences. Standard of protection against future increase in flows. Canal direct defences should be constructed so that reinstatement of the canal footpath results in a safer footpath with more difficult access to dangerous open water. Reconstruction of the existing embankments should result in a more robust defence where they have previously failed.
Option 2 – Area A direct defences Area B direct defences, flood gate, canal bridge and weir removal.	0.5% AP – 200 year	Properties at risk are not protected with the inclusion of climate change.						Not cost effective due to expense of defences and high residual risk, benefit cost ratio of 0.94.	
Option 3 – Area A undefended Area B direct defences, flood gate, canal bridge and weir removal.	3.33% AP – 30 year (Area B 0.5% AP – 200 year)	Properties at risk are not protected with the inclusion of climate change.			Large direct defences required. Modifications to privately owned canal. Social implications of not protecting the full area of Inverurie and Port Elphinstone.	Large residual risk due to large costs during the low probability events and no protection of properties in area A greater than the 30 year event. Consideration of relocation in Area A in the future as well as adaptation to direct defences to include climate change.		Benefit cost ratio of 1.05.	
Option 4 – Area A undefended Area B direct defences, flood gate, canal bridge and weir removal.	3.33% AP – 30 year (Area B 1% AP – 100 year)	Properties at risk are not protected with the inclusion of climate change.						Benefit cost ratio of 1.23.	
Option 5 – Area A direct defences Area B direct defences, flood gate, canal bridge removal.	0.5% AP – 200 year (Kirkwood 0.1% AP – 1000 year).	Properties at risk are not protected with the inclusion of climate change with the exception of Kirkwood.			High direct defences required for a long extent. Modifications to privately owned canal.	Some residual risk from large costs during the low probability events. Further adaptation to the direct defences particularly the non-residential properties at Keithhall Road would significantly reduce this.		Benefit cost ratio of 1.28.	
Option 5b – Area A direct defences Area B direct defences, flood gate, canal bridge removal.	0.5% AP – 200 year plus CC (Kirkwood 0.1% AP – 1000 year)	All properties protected.						Benefit cost ratio of 1.12.	
Option 6 – Area A direct defences Area B direct defences on existing alignment, flood gate, canal bridge removal. (SW WWTW unprotected)	0.5% AP – 200 year (Kirkwood 0.1% AP – 1000 year)	Properties at risk are not protected with the inclusion of climate change with the exception of Kirkwood.	No significant environmental benefit or impact from existing conditions.	RBMP impacts of channel constriction from direct defences on the banks.				Benefit cost ratio of 1.87.	
Option 6b – Area A direct defences Area B direct defences on offset alignment, flood gate, canal bridge removal. (SW WWTW unprotected)	0.5% AP – 200 year (Kirkwood 0.1% AP – 1000 year)	Properties at risk are not protected with the inclusion of climate change with the exception of Kirkwood.	Environmental benefit from formalisation of green space Minor disturbance during construction.	RBMP benefit of reconnection to a more naturalised floodplain by setting back existing embankments. Minor amounts of further channel constriction from additional direct defences, mainly during high flooding events. (>100 year)				Benefit cost ratio of 1.53.	

Negative | Neutral | Positive

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AMAX	Annual Maximum
AP	Annual Probability
FEH	Flood Estimation Handbook
FPS	Flood Protection Scheme
GIS	Geographical Information System
GL	General Logistic Distribution
LiDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
NFM	Natural Flood Management
NGR	National Grid Reference
OS	Ordnance Survey
PLP	Property Level Protection
PVd	Present Value Damages
QMED	Median Annual Flood (with return period 2 years)
RBMP	River Basin Management Plan
ReFH	Revitalised Flood Hydrograph method
RR	Rainfall-Runoff
SEPA	Scottish Environment Protection Agency
SoP	Standard of Protection
SW	Scottish Water
WWTW	Waste Water Treatment Works

Supporting Documents

Hydrology report - AIZ-JBAU-IK-00-RP-HM-0002-Hydrology-A1-C01.pdf

Information review - AIZ-JBAU-IK-00-RP-HM-0001-Information_Review-A1-C01.pdf

Asset condition assessment report - AIZ-JBAU-IK-00-RP-C-0001-Asset_Condition_Assessment-A1-C01.pdf

NFM report - AIZ-JBAU-IK-00-RP-EN-0001-NFM_RBMP_Report-A1-C01.pdf

Preliminary Ecological Appraisal - AIZ-JBAU-IK-00-RP-EN-0002-Inverurie_PEAR-A1-C01.pdf

Modelling report - AIZ-JBAU-IK-00-RP-HM-0005-Modelling_Report-A1-C01.pdf

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

Option drawings - supplied as PDF's

1 Introduction

1.1 Legislative framework

Inverurie and Port Elphinstone are part of the North East Local Plan District (LPD) and is categorised as a Potentially Vulnerable Area (PVA) (06/13) with an area of 60 km^2. The details for this LPD, are contained in the North-East Flood Risk Management Strategy (FRMS)[1] and the North East Flood Risk Management Plan (LFRMP)[2]. Within this PVA a number of recommendations were made to undertake site specific detailed flood protection studies (amongst other flood risk management activities) to better inform the current flood risk to these communities and to investigate options for mitigation. Nationally Inverurie and Port Elphinstone are ranked 57 out of 168 PVA's but 2 out of 12 within the Aberdeenshire Council authority area.

Under the Flood Risk Management (Scotland) Act 2009, this report forms part of the appraisal study for Inverurie and Port Elphinstone commissioned by Aberdeenshire Council and follows SEPA's Options appraisal for flood risk management guidance[3].

Background

This flood study was commissioned to gain a greater understanding of the flood mechanisms in each community, improve upon SEPA's flood risk maps, and provide an appraisal of options which could reduce flood risk.

The study aims to better assess current flood risks in the community by undertaking a review of past flood events; generating updated and detailed flood maps, determining the likely risk to different properties; and to propose a set of mitigation measures to reduce the flood risk to an acceptable level. A set of reports has been prepared to summarise the work undertaken and to provide a detailed explanation of the various steps carried out. The short-listed and preferred options will be presented to the public to gain their input into the designs and to ensure that the preferred set of interventions offer a sustainable method of flood protection whilst seeking to benefit the environment and the community of interest.

The major watercourses which cause fluvial flood risk to Inverurie and Port Elphinstone are the River Don and River Urie. The study area is shown in Figure 1-1.

1 North-East Flood Risk Management Strategy http://apps.sepa.org.uk/FRMStrategies/pdf/lpd/LPD_06_Full.pdf [accessed 10 November]

2 North East Flood Risk Management Plan http://www.aberdeenshire.gov.uk/media/17174/north-east-local-flood-risk-management-plan-2016-2022-web-version.pdf [accessed 10 November 2017]

3 Flood Risk Management (Scotland) Act 2009, Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities, First Edition, May 2016

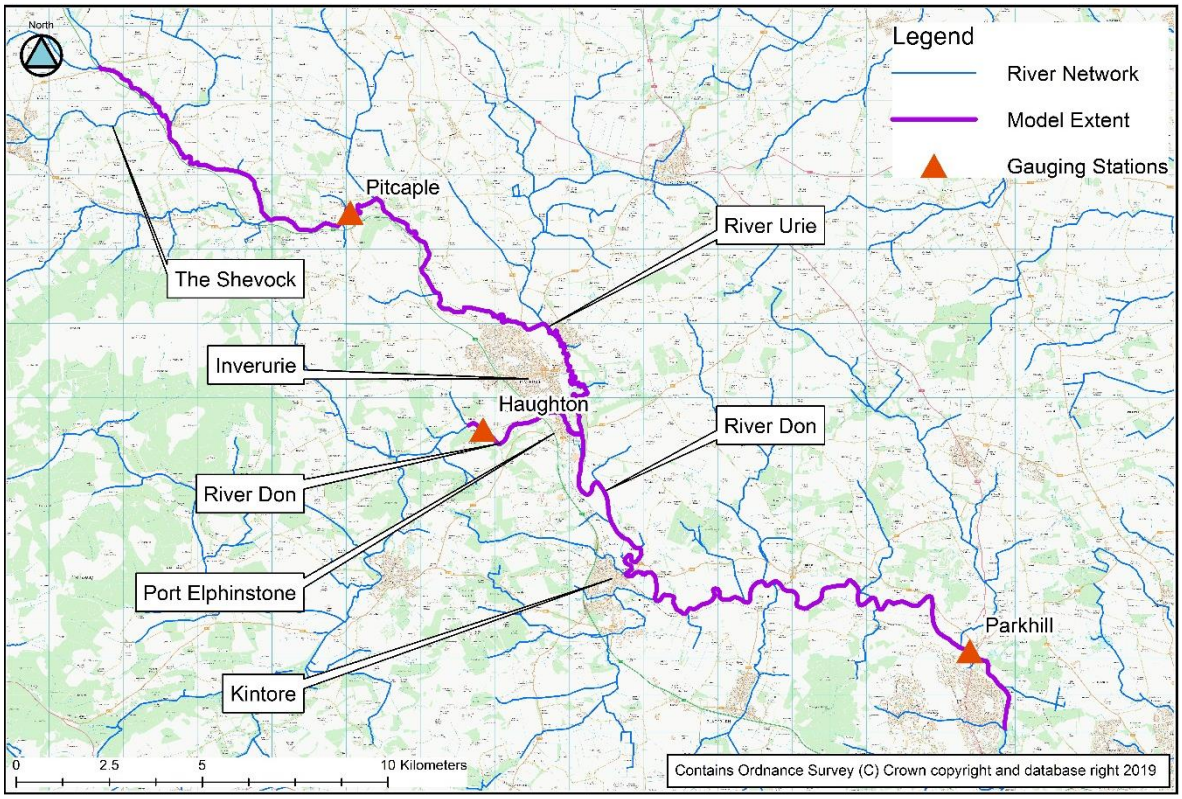


Figure 1-1: Study Extent

There is an extensive flood history within the area of Inverurie and Port Elphinstone, the most significant event was experienced in 2016 (Storm Frank). A review of the flood history is explained further in Section 2.1. Many properties have been highlighted at risk from previous flood events where flooding commences during medium likelihood events but is far more prominent during the low likelihood events.

1.2 Aims and objectives

The options appraisal seeks to provide information appropriate to Aberdeenshire Council to inform their decision on the most sustainable strategy for flood risk management to the community of Inverurie and Port Elphinstone that contributes, where possible, to achieving River Basin Management Planning (RBMP) objectives and is 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 with the inclusion of a 24% increase to flow from climate change, if feasible or a lower magnitude event in other cases.

b. Highlight opportunities to reduce river flows through Natural Flood Management practices and quick wins.

c. Provide recommendations on further supplementary studies required to understand the full flood risk to the properties.

2 Preliminary Investigations

The full reports for each of the sections below are referenced in the Supporting Documents section at the start of this report.

2.1 Flood history

The earliest recorded flooding on the River Don was in 1768. Prior to 2016, the most notable flood event occurred in 1829, causing widespread flood inundation and impacts on agriculture; infrastructure and residential dwellings. At the time, the event was described as follows: "In the flood of August 1829, it rose four inches higher than in that of 1768, and did much damage…0.1 m above 1768. Flooding 12-14 foot above ordinary level. Mill-house of Kemnay swept away"[4]. The most recent event occurred in 2016 also causing wide scale flood inundation to communities in: Port Elphinstone; Inverurie; Kemnay; Alford; Dyce; Cothal; Kildrummy; Burnhervie; Bellabeg; Glenkindie and Kintore. This flood was the largest recorded flow at the Parkhill gauging station (stage of 5.56 m) since records began in 1970.

In summary, the key events in which Inverurie, Port Elphinstone or Kintore experienced flooding were as follows: 1829, 1924, 1995, 2002, 2003, 2004, 2005, 2006, 2009, 2010, 2015 and 2016. Key events are summarised below in Figure 2-1.

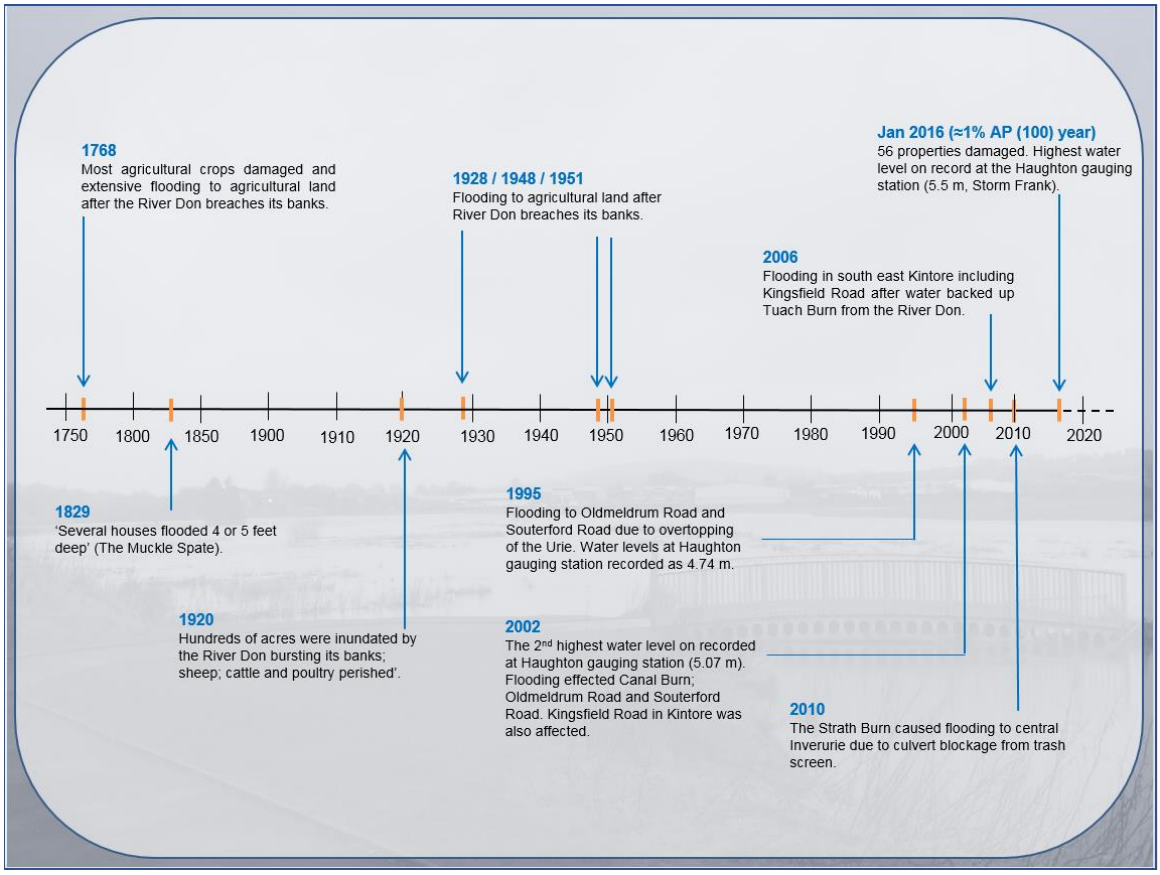


Figure 2-1: Key flood events in Inverurie and Port Elphinstone

4 Lauder, T.D., (1830) The Great Floods of August 1829, In The Province of Moray and Adjoining Districts [Online]. Third edition. Elgin: R. Stewart. [Accessed 27/11/2017. Available from: https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up]

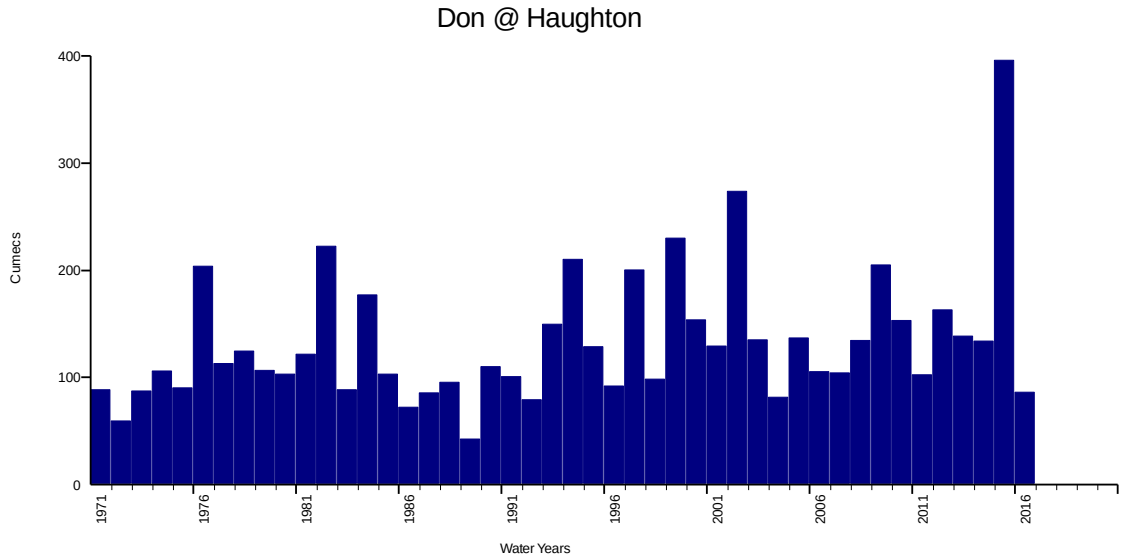


Figure 2-2: AMAX series for the River Don at Haughton

Figure 2-2 shows the annual maxima series (AMAX) series for the River Don at Haughton. This shows the significant difference in the 2016 flow compared to previous years. The 2016 event (Storm Frank) is estimated to have a return period of c. 105 years, while the second largest event on record (Nov 2002) is estimated to have a return period of c. 30 years.

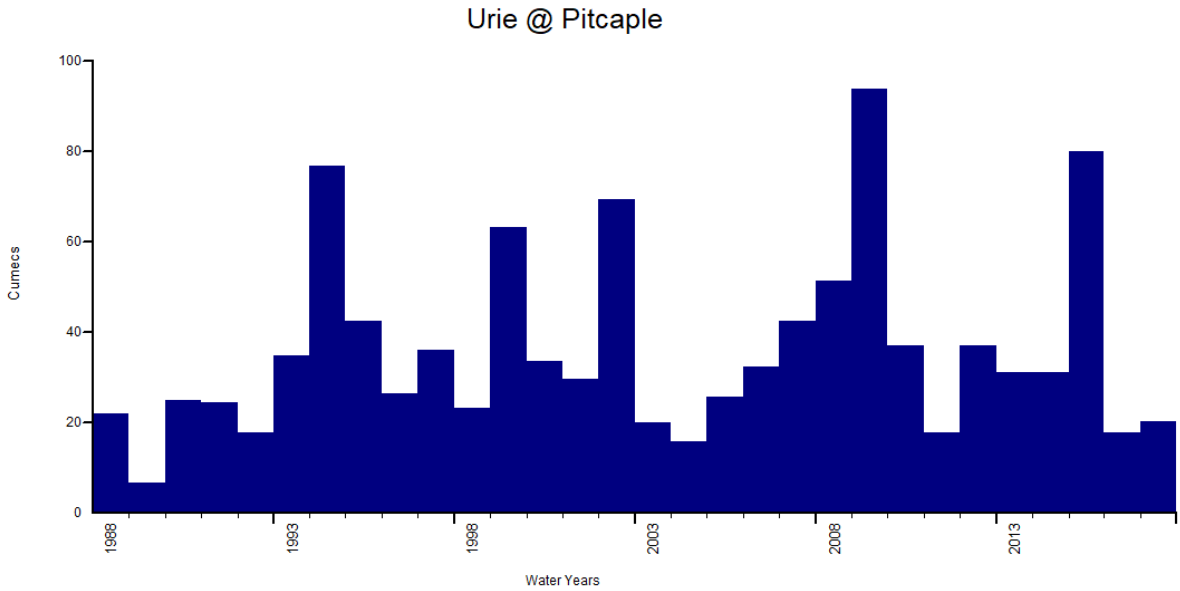


Figure 2-3: AMAX series for the River Don at Haughton

Figure 2-3 shows the annual maxima series (AMAX) series for the River Urie at Pitcaple. The 2016 event on the Urie was significant though it is not the highest event estimated to have a return period of c. 45 years where the 2009 event has a return period of c. 80 years.

2.2 Hydrology

A summary of the flows derived from the hydrological analysis are shown below. The flows were achieved using the statistical analysis when analysing Pitcaple, Haughton and Parkhill gauging stations.

Table 2-1: Hydrology Inflows

Annual Probability [AP] (%)	Return Period (years)	River Don at Haughton Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Urie at Pitcaple Gauging Station. Enhanced Single Site Statistical Flow: GL (m^3/s)	River Don at Parkhill Gauging Station. Single Site Statistical Flow: GL (m^3/s)
50	2	111.7	31.3	160.4
20	5	158.1	44.9	234.3
10	10	196.4	55.0	292.7
4	25	258.3	70.0	383.3
3.33	30	272.6	73.3	403.9
2	50	317.2	83.2	466.7
1.33	75	357.9	91.8	522.9
1	100	390.1	98.3	566.6
0.5	200	480.5	116.0	687.1
0.2	500	635.1	143.8	885.9
0.1	1000	786.0	168.9	1073.4
0.5 +CC	200 +CC	595.9	143.8	852.0
2016 event	-	396.2	63.9	576.2

2.3 Survey data

As shown in Figure 2-4 below, survey was obtained from two different sources. The upstream extent of the River Urie, the River Don upstream of Haughton gauging station and around Parkhill gauging station were provided by SEPA and carried out by Six West, dated December 2016. The sections in between were carried out by Malcolm Hughes Loys Surveys on behalf of JBA Consulting and dated April 2018.

The survey data consists of:

- Cross sectional data files for Flood Modeller.
- An Excel spreadsheet of all recorded cross section points.
- CAD drawings of each cross section.
- GIS cross section location shapefiles.
- PDFs showing the locations, long section and section view through each cross section.
- Photos of each cross section including upstream, downstream, left bank and right bank.

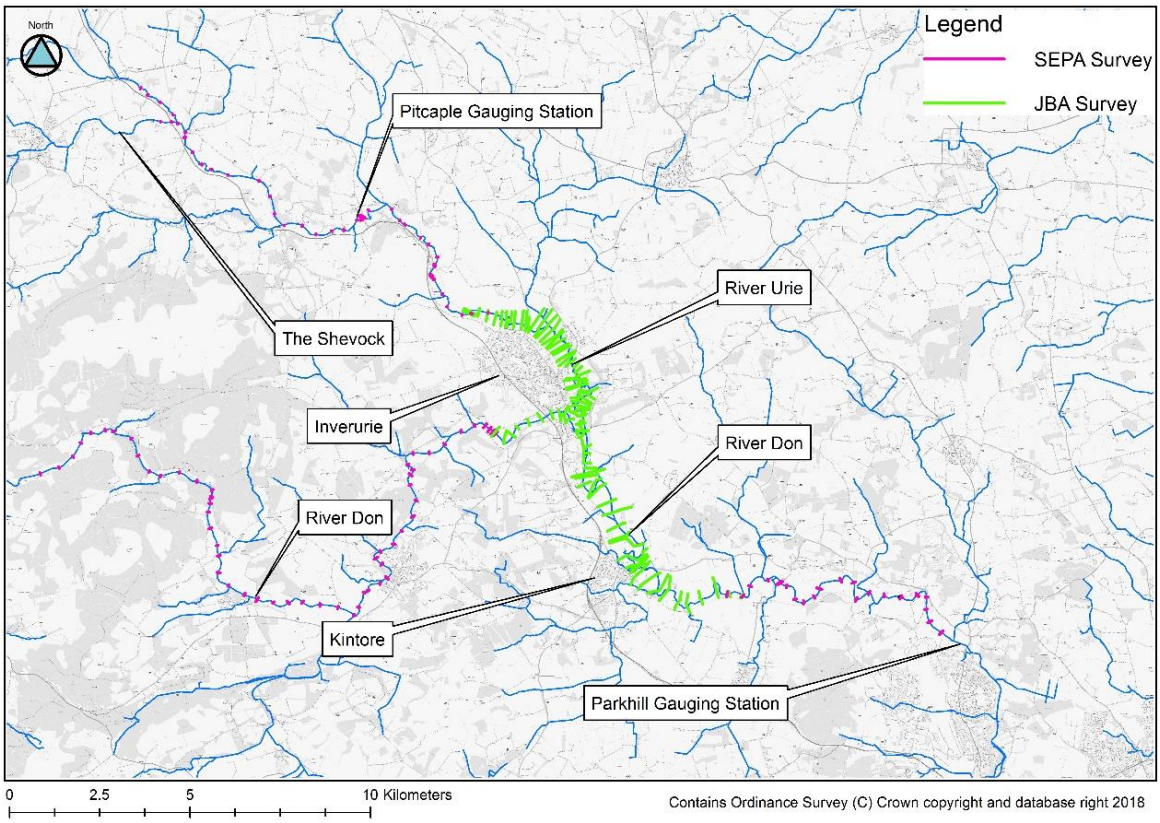


Figure 2-4: Survey Location

Property threshold levels were also surveyed by JBA in October 2018 for all properties falling within the 0.1% AP (1000 year) event flood envelope. A further buffer has been added to the 0.1% AP (1000 year) event of 50m where any additional properties captured have had threshold levels extracted from the 0.25m LiDAR. This is to account for a potential increase from the Do Nothing scenario though it is unlikely these properties will be flooded.

To gain a full appreciation of the study area an asset condition survey was also carried out in April 2018 to understand the condition of all the existing structures that cross the watercourse, including their risk of blockage.

2.4 Preliminary Ecological Appraisal

A variety of habitats were identified on the site walkover, including tall ruderal, fen, mixed and semi-natural woodlands, arable and neutral semi-improved grassland. Priority habitats recorded on the site include coniferous and broadleaved woodlands, Lowland Fens, Rivers and Streams (Mesotrophic running water) and Neutral Grassland (Lowland Meadows), these should be avoided during works, or mitigation and compensation may be required. The ecological value of the site was determined to be of moderate to high value, as the structural diversity across the surveyed area provided foraging and refuge opportunities for Otters, Bats, small mammals, Badgers, Red Squirrel, Fish, Freshwater Pearl Mussels and invertebrate assemblages. In addition, the fen, the river corridor, marginal habitats and the connected floodplain developed a good habitat connectivity corridor at a landscape scale.

There are no statutory and non-statutory designated conservations sites within 2 km of the site. There are existing records of a range of protected species within a 2 km radius..

On confirmation of the exact works, a series of targeted protected species surveys are likely to be necessary. These could include targeted surveys for Otters, fish and Freshwater Pearl Mussels, bat activity surveys and nesting bird surveys. The surveys must be undertaken in suitable survey seasons. If mature trees are to be removed then nesting bird, bat roost assessments and Red Squirrel surveys may be necessary.

Invasive non-native species are present, data retuned from NESBReC for invasive non-native plant species revealed a number present within the study area, including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and

Rhododendron. The field survey detected the presence of two INNS; Giant hogweed and Himalayan Balsam. Both were identified in extensive stands along both watercourses, particularly the downstream extent of the River Urie, for a detailed extent of the identified INNS see Appendix A in the JBA Consulting preliminary ecology report.[5] A detailed mapping survey should be undertaken in the summer once the works plans are finalised but before they start. The locations can be used to determine the mitigation measures including removal of the species or marking out exclusions zones.

A Water Framework Directive Assessment should be undertaken prior to the works to ensure that the works are in line with European Legislation. Given the potential for in-channel nature of the works, pollution prevention measures should be adopted to prevent contamination of the watercourse.

2.5 Natural Flood Management

An NFM study was conducted within the full catchment of the Inverurie and Port Elphinstone. An overview of the key areas that are recommended from the study are shown in Figure 2-5 below.

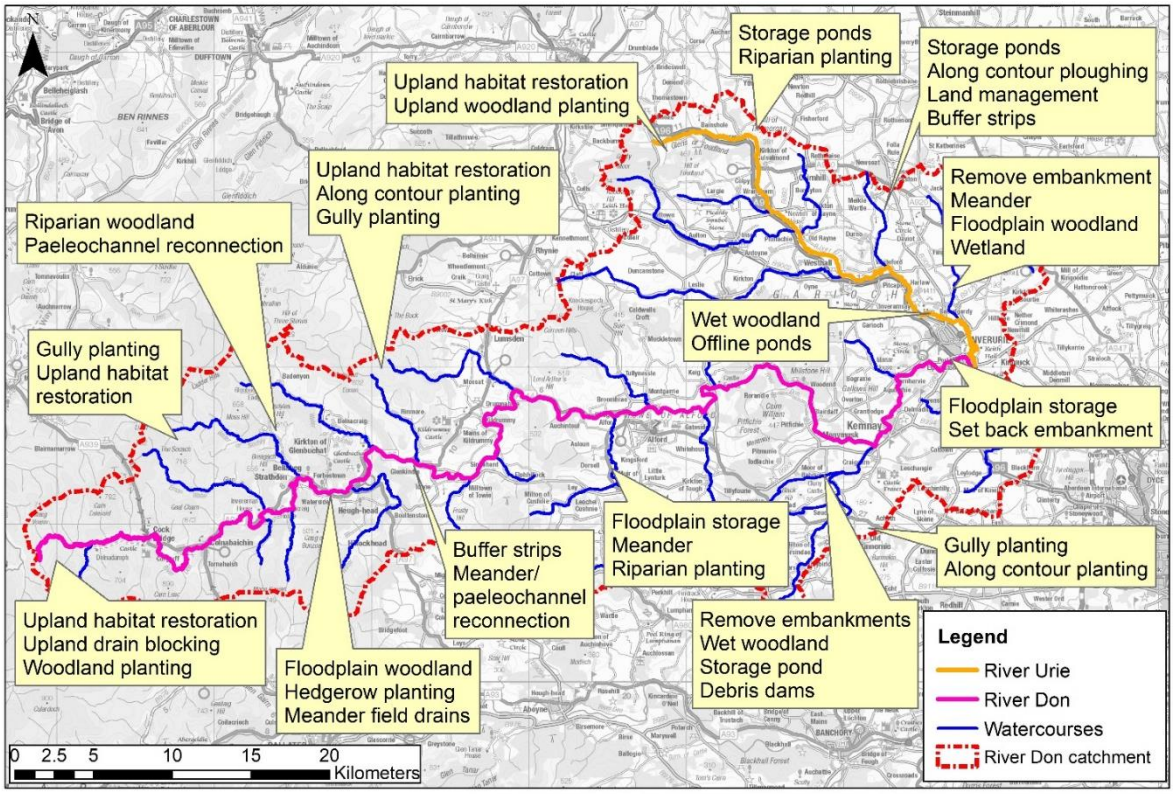


Figure 2-5: Summary of NFM options within the River Don and Urie catchment

An overview of the key areas that are recommended from the study are shown in Figure 2-5. Key recommendations include:

- Increased vegetation cover.
- Working within and on the banks of the channel.
- Land management.
- Runoff management.

5 Primary Ecological Appraisal Report, JBA Consulting, May 2018

2.6 Hydraulic modelling

The hydraulic model is a 1D/2D linked model, utilising Flood Modeller Version 4.3.6458.29637 for the 1D and TUFLOW Version 2016-03-AE-iDP-w64 for 2D components respectively. Both watercourses; River Urie and River Don, have been modelled in 1D up to top of bank. The out of bank region has been represented in 2D for the entire extent. An overview of the 1D and 2D extents are shown in Figure 2-6 below.

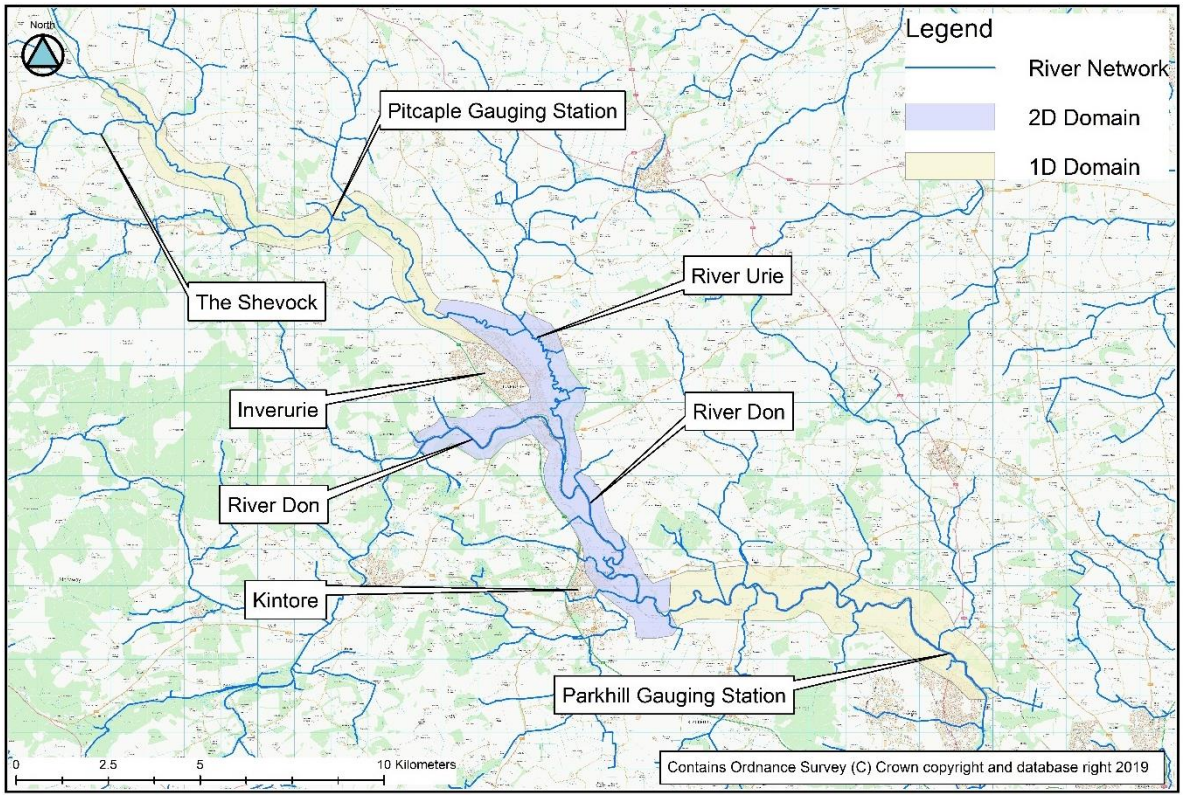


Figure 2-6: Watercourse locations and model extent

2.7 Storm Duration Analysis

The River Don and Urie are sourced from different catchments, the Don being a larger catchment. When comparing the Haughton (River Don) and Pitcaple (River Urie) gauging stations 18 out of 29 flood events coincided in terms of date where for those which coincide the peaks ranged from 0.25 hours to 9 hours apart. In general the River Urie peaked before the Don. The model has been run with a 39 hour critical storm duration on both the River Urie and the River Don. This results in Pitcaple gauging station peaking 5 hours before Haughton gauging station which is in line with observed events.

A sensitivity analysis was also conducted reducing the storm duration to 17 hours. This made a minimal difference to the results within the critical area of Inverurie and Port Elphinstone with a maximum flood depth difference of 0.01 m.

3 Appraisal Approach

3.1 Overview

The purpose of this report is to conclude and appraise the design options which will be taken forward to defend against the flood risk within Inverurie and Port Elphinstone. A 1D/2D Flood Modeller and TUFLOW model has been built and calibrated to analyse the flood risk within the study area. This model has been used to produce Do Minimum and Do Nothing flood maps as a baseline in order to analyse the damages and flood extent. A long list of options based on this mapping has been created for all potential options to defend the study area, this has then been broken down and feasible options have been shortlisted and then appraised.

3.2 Problem definition

There are currently 90 properties at risk from the 0.1% AP (1000 year) event under present conditions within Inverurie and Port Elphinstone from the River Urie and River Don. Flooding is estimated to begin at the 10% AP (10 year) flood event under existing conditions. There are at present two embankments within the area of study; Davidson Field embankment and Scottish Water embankment. There has been some uptake of Property Level Protection (PLP) products by residents.

4 Do Minimum and Do Nothing

4.1 Do Minimum results and assumptions

The Do Minimum results represent the present-day scenario in which all of the watercourses and structures are maintained and replaced if they deteriorate to a point that is unacceptable. Manning's 'n' roughness represents current conditions and no bridge blockage is assumed. The two existing embankments have 0.6 m freeboard removed to represent the section of the embankment that was designed to protect against flood risk. Figure 4-1 shows the 0.5% AP (200 year) + climate change results for the Do Minimum scenario.

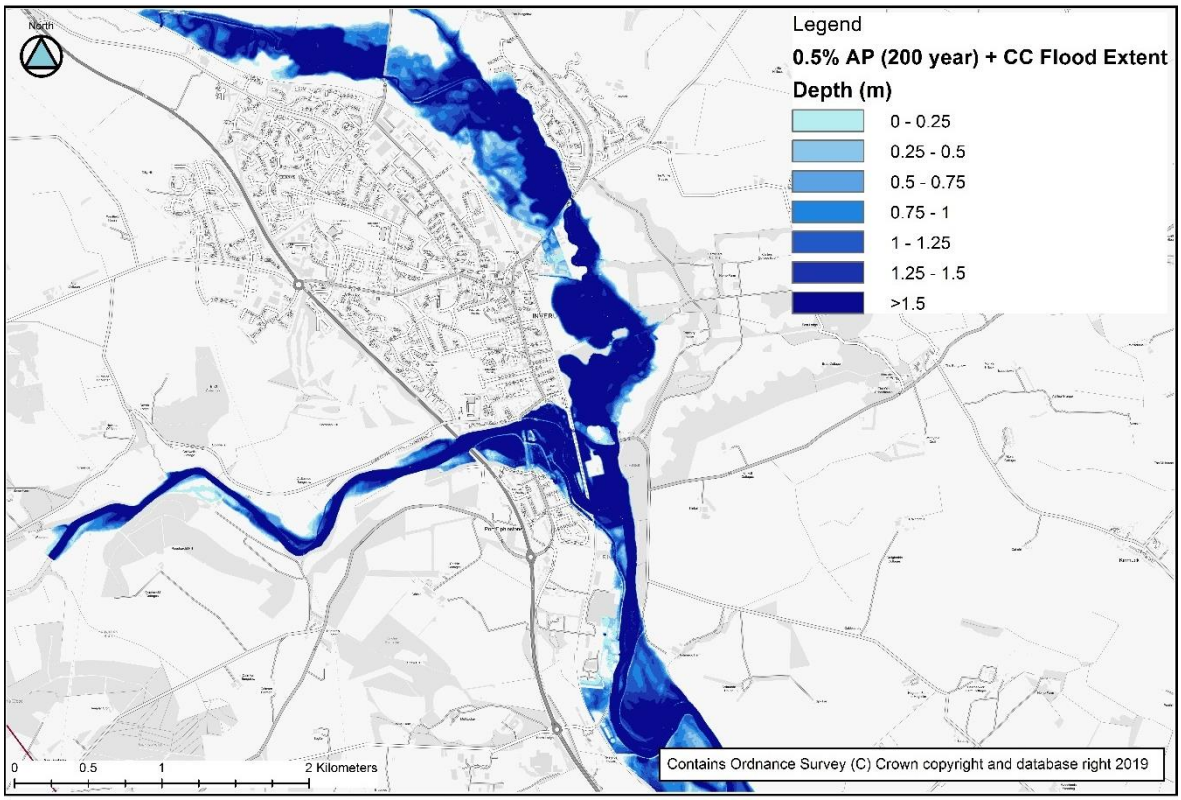


Figure 4-1: Do minimum 0.5% AP + climate change flood extent

4.2 Do Nothing results and assumptions

The Do Nothing results represent the 'walk away' scenario where all watercourse and structure maintenance stops. This therefore represents a scenario with no intervention in the natural processes and serves as a baseline against all other options. The Do Nothing assumptions include an increase in Manning's 'n' roughness particularly where banks will no longer be maintained. It also includes blockage to structures at risk, see Appendix A for a full list of the Do Nothing assumptions on the River Urie and River Don. The two existing embankments have 0.6 m freeboard removed to represent the section of the embankment that was designed to protect against flood risk. Figure 4-2 below shows the 0.5% AP + climate change results for the Do Nothing scenario.

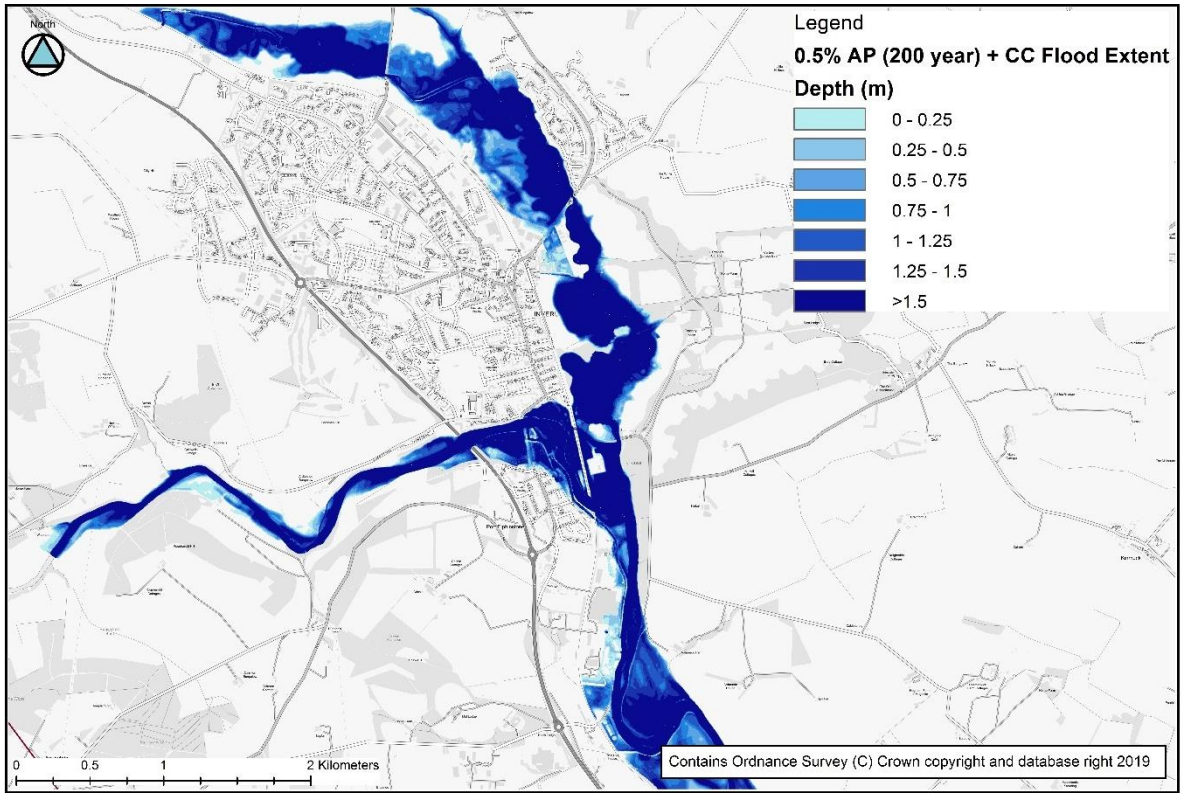


Figure 4-2: Do nothing 0.5% AP + climate change flood extent

For the 100 year appraisal period the Do Nothing damages are used as a baseline against all other options, due to the embankments having a history of breaching during the 2016 event as of year 20 the Do Nothing scenario will include full breach of the embankments. See Appendix A for full details on the breaching scenario.

4.3 Kirkwood Commercial Park assumptions

The old mill at Kirkwood Commercial Park is currently under redevelopment, plans on the Aberdeenshire planning portal[6] show redevelopment of some of the existing infrastructure while demolishing some of the buildings. The approach taken for damages within this area is discussed below with the aid of Figure 4-3.

6 https://upa.aberdeenshire.gov.uk/online-applications accessed 02/05/2019

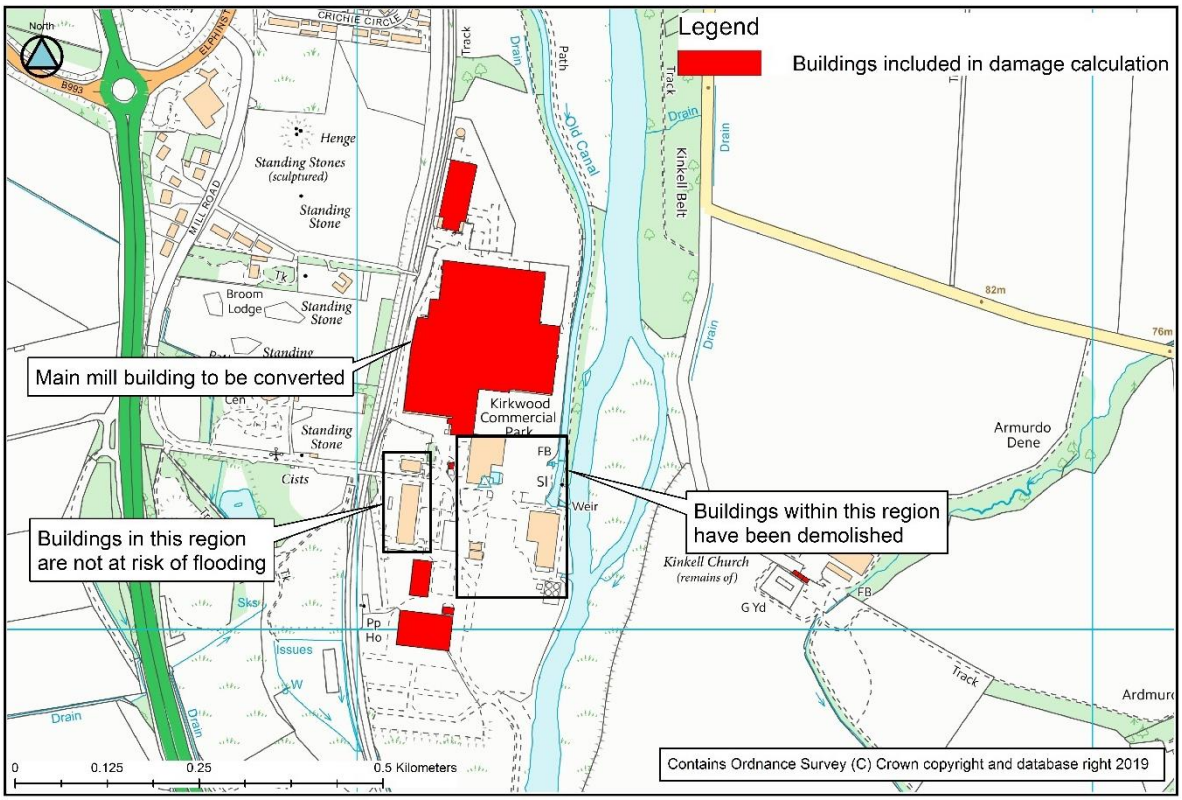


Figure 4-3: Kirkwood buildings for damage calculation

Figure 4-3 shows the buildings that have been included in the damage calculation using existing MasterMap information but combining information from the planning portal and online aerial photography to include buildings which have been demolished. As the mill is no longer in operation all buildings have been designated a code in line with a warehouse.

4.4 Current Standard of Protection (SoP)

The figures below show the SoP each property within Inverurie and Port Elphinstone has from fluvial flood risk. SoP 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 3.33% AP (30 year) SoP would be expected to flood at the 2% AP (50 year) event. Flooding is said to occur when the modelled flood level exceeds the building floor level. Floor level (threshold) data for all properties was collected by JBA's surveyors.

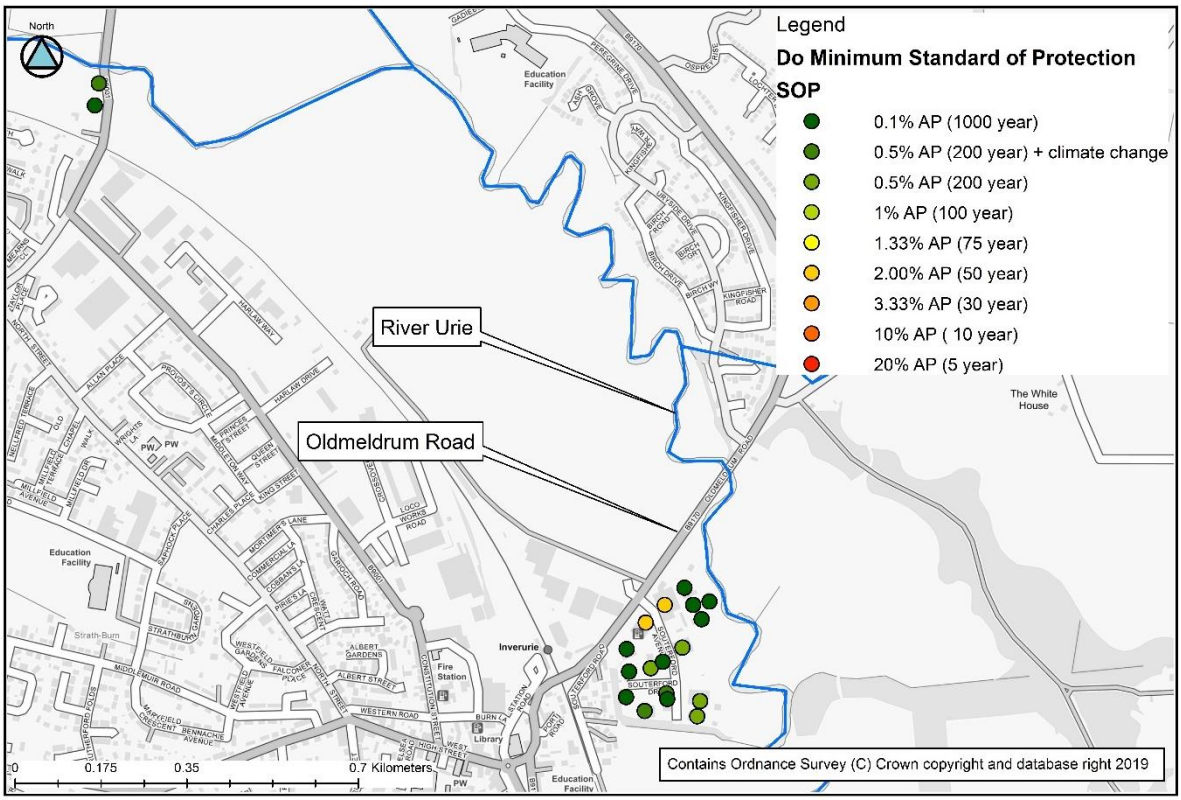


Figure 4-4: Oldmeldrum Road Standard of Protection

Figure 4-4 shows that the properties around Oldmeldrum Road start to flood at the 1.33% AP (75 year) event with a SoP of 2% AP (50 year).

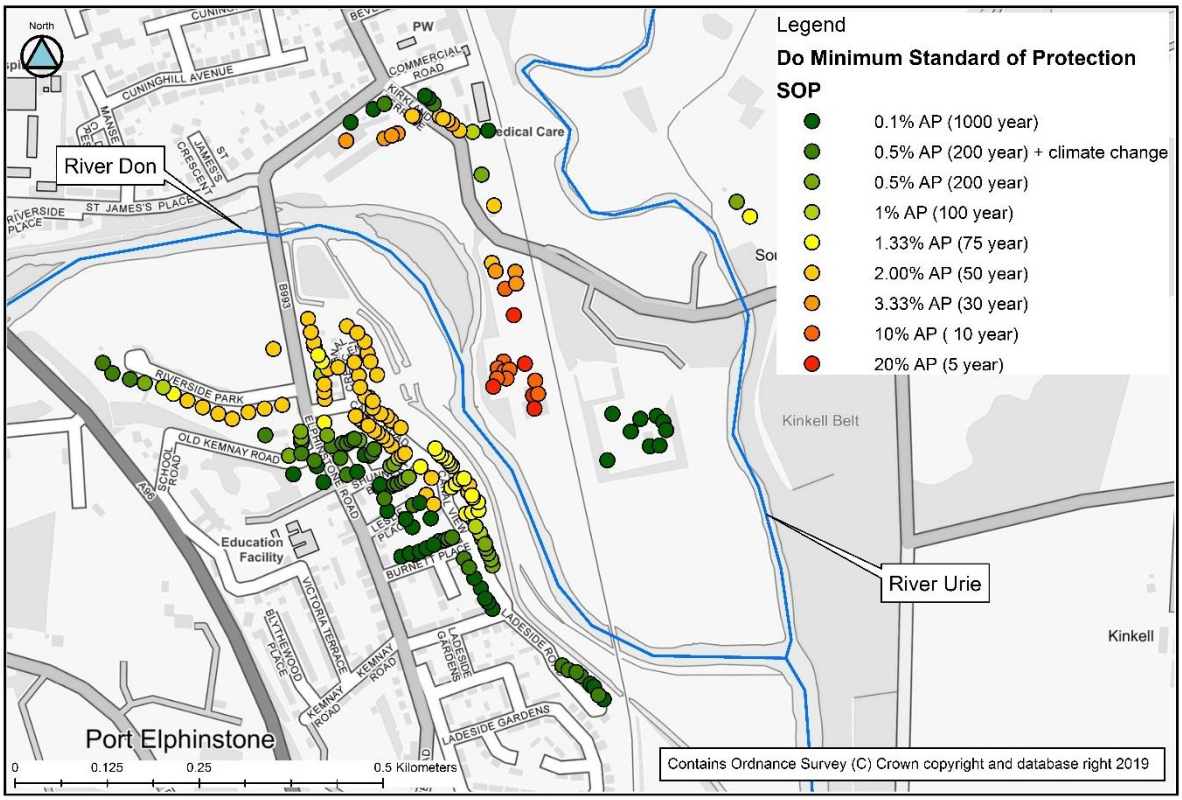


Figure 4-5: Port Elphinstone and South Inverurie Standard of Protection

Figure 4-5 shows that properties within Port Elphinstone commence flooding from the 1.33% AP (75 year) event. The Scottish Water treatment works floods from the 10% AP (10 year event) with a far lower SoP then the rest of the area.

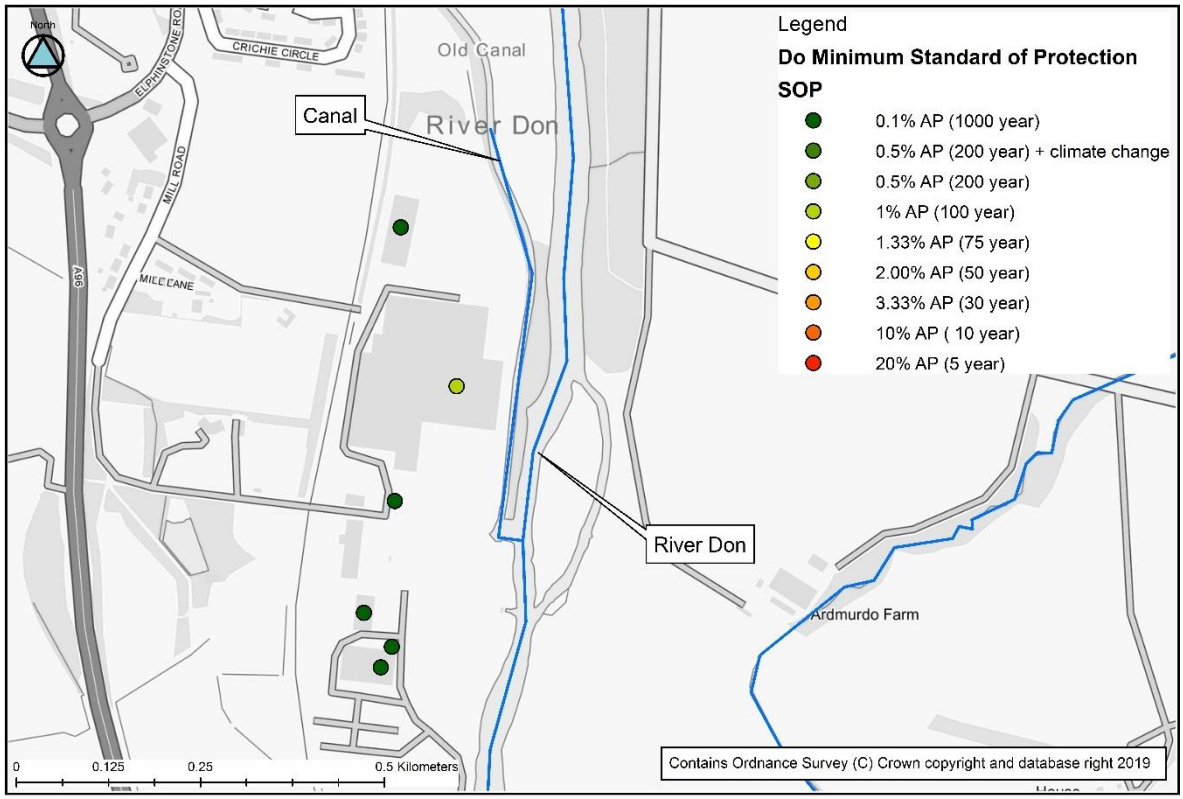


Figure 4-6: Kirkwood Standard of Protection

Figure 4-6 shows that only one property is at risk below the 0.1% AP (1000 year) event. The main old mill building has a SoP of 1% AP (100 year).

Overall, the SoP within Inverurie and Port Elphinstone is mixed commencing at 20% AP (5 year) for the Scottish Water treatment works with a significant amount of properties only achieving a SoP of 2% AP (50 year). This appraisal study will aim to protect the properties against the 0.5% AP (200 year) + climate change event, a breakdown of the properties at risk from this event are as follows:

- Oldmeldrum Road - 6 properties
- Port Elphinstone and South Inverurie - 69 properties
- Kirkwood Commercial Park - 1 property

4.5 Accounting for climate change

Under the Climate Change (Scotland) Act (2009) local authorities have a duty to use an evidence-based approach to develop means to reduce the impact of climate change through mitigation measures (reducing emissions), planning to adapt to a changing climate and acting sustainably. This project appraisal fulfils the ‘adaptation’ and ‘acting sustainably’ duties.

At the outset of the 100 year appraisal period property Average Annual Damages (AAD) from the baseline Do Nothing scenario were used. These damages increase by linear interpolation to the year 2080 at which point the AAD from a set of model runs taking climate change into account is used. As discussed in section 4.2 a breach scenario is also accounted for where at year 20 the damage curve changes to one which removes the embankments which have previously breached, climate change interpolation continues on this new curve.

5 Flood Risk Management Options

5.1 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 Benefit Cost Ratio (BCR) when measured in parallel with other success criteria.
7. Should incorporate National, Regional and Local agendas/objectives.

5.2 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 (200 year) flood. 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.

Based on the above guidance the aim of the scheme will be to assess options up to the 0.5% AP (200 year) plus climate change flood if possible, where 0.5% AP (200 year) will also be assessed as the lower standard.

5.3 Short term structural and maintenance recommendations and quick wins

Several measures or short term 'quick wins' have been identified that cover a range of aspects from maintenance to small scale works. They are summarised in Table 5-1.

5.3.1 Short term structural and channel maintenance and quick wins

Table 5-1: Short term structural and channel maintenance and quick wins for Inverurie and Port Elphinstone.

Problem	Actions	Photo
Asset number 7 - Outfall not visible. Assumed to be below water level. NGR NJ 77124 20399	Fit non-return valve if it becomes a source of flooding. 300 mm dia. Pipe at outlet (not visible when surveyed)	 ***Scottish Water outfall upstream of A96 at Port Elphinstone***
Asset number 12 - Outfall not visible. Assumed to be below water level. NGR NJ 77561 20591	Fit non-return valve if it becomes a source of flooding. 300 mm dia. Pipe at outlet (not visible when surveyed)	 ***Scottish Water outfall at Davidson Field***
Asset number 14 - Outfall with gate. NGR NJ 77659 20646	Fit non-return valve if it becomes a source of flooding.	 ***Scottish Water outfall downstream of Elphinstone Road Bridge***

Problem	Actions	Photo
Asset number 17 - Vegetation growth at all sides of structure. Corrosion of pipe grill. Fixings still present. Eroded banks. Flood debris in surrounding area. Scottish Water CSO outfall 8501 from Inverurie WWTW likely to cause flooding during high flows and event NGR NJ 77884 20600	Fit a non-return valve, remove debris, remove pipe grill.	 ***Scottish Water outfall at bund***

The locations of the above structures are shown in Figure 5-1 below.

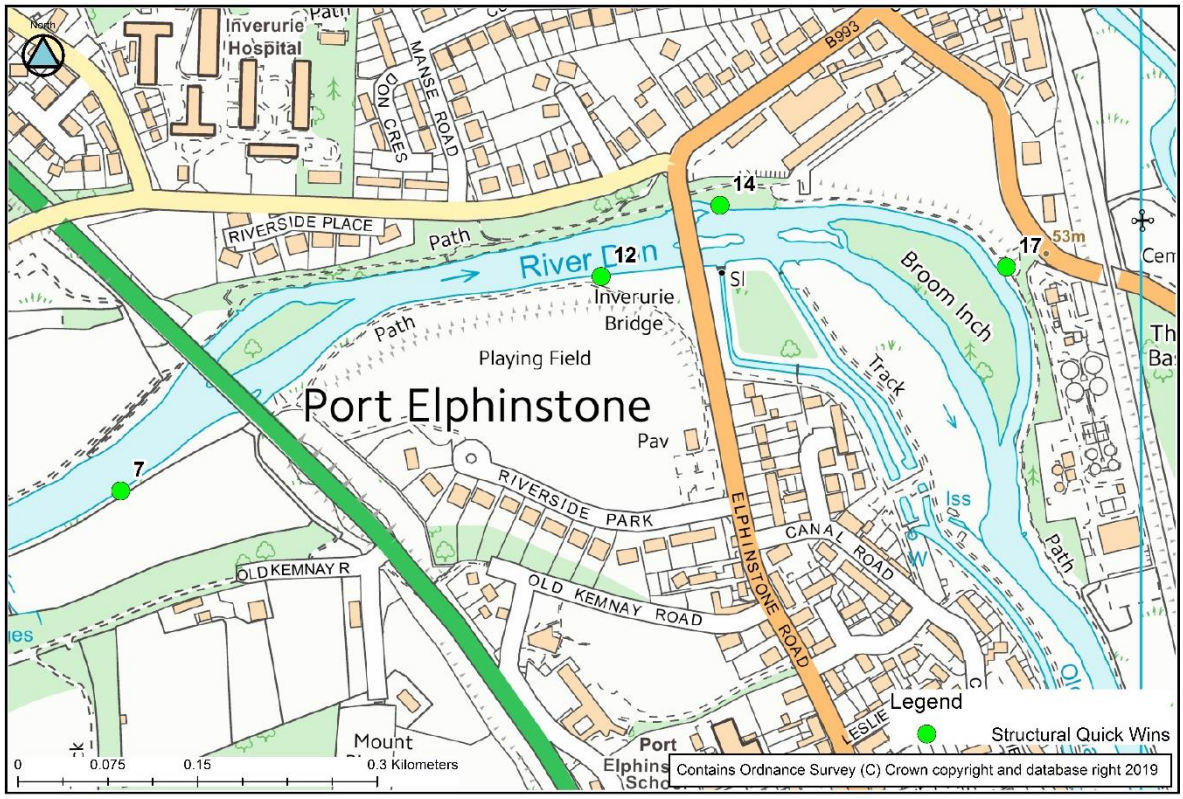


Figure 5-1: Quick win locations from asset condition report[7]

7 Inverurie Asset Condition Assessment, JBA Consulting, 04 May 2018

5.4 Non-structural flood risk management recommendations

5.4.1 Flood warning

A flood warning system is currently in place around Inverurie and Port Elphinstone, it is recommended to continue to maintain the system which is part of the Don river flood warning scheme.

The target area that currently has a flood warning scheme in place starts downstream of Souterford road bridge on the River Urie, upstream of the A96 and Davidson Field on the River Don to downstream of Kirkwood Commercial Park on the River Don.

5.4.2 Emergency action plans

Aberdeenshire Council has an overarching Flood Response Plan, which is coordinated through the Responders identified under the Civil Contingencies Act 2004. The aim of the plan is to set out arrangements to deal effectively with flood risk. At predetermined trigger levels flood alerts and warnings will be issued through SEPA's flood forecasting and warning service (Floodline) and Aberdeenshire Council will conduct assessments at known hotspots and prepare resources as required. Aberdeenshire Council will also coordinate measures in conjunction with the other Responders. The emergency response process is coordinated through regional and local resilience partnerships. This response may be supported by the work of voluntary organisations[8].

This emergency plan should be updated regularly as new information becomes available. 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).

5.4.3 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. Flood Action Groups are well known to assist with this awareness raising and resilience.

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

8 North East Local Plan District - Local Flood Risk Management Plan Inverurie and Kintore, Aberdeenshire Council, https://www.aberdeenshire.gov.uk/media/17360/pva-06_13-inverurie-and-kintore.pdf

5.4.4 Community sandbag stores

Aberdeenshire Council continues to use community sandbag stores located at publicly accessible areas such as outside Harlaw Road at the main road depot. The Council should review the location of the stores and investigate if additional stores are necessary to cover the full area of Inverurie and Port Elphinstone.

It is recommended that the Council considers the use of the flood 'pod' system: community storage boxes, which contain flood sacks which are purpose designed bags filled with absorbent material. The key advantage of this approach is that they can be distributed before a flood. 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 Inverurie and Port Elphinstone. This approach would need to be combined with the flood warning system currently in place.

5.4.5 Property Level Protection (PLP)

Aberdeenshire Council currently offer a discounted PLP scheme to properties at risk of flooding, selling discounted PLP products to residents through a capped council-funded subsidy. The scheme makes manual PLP products more affordable than they would otherwise be and there has been some uptake to date particularly in Port Elphinstone. Manual PLP products that must be installed in advance of a flood event are in general seen as a short-term solution. Nevertheless, a full PLP scheme using passive (or 'automatic') products will be considered alongside the other options in the investment appraisal. Whether full funding would be provided through a flood protection scheme or if resident contributions would be sought is not considered at this stage.

5.4.6 Natural Flood Management (NFM)

The catchment for the Don and Urie have a multitude of opportunities to capitalise on in order to provide attenuation of flooding.

As summarised in section 2.5 a number of primary opportunities exist and may be considered by the Council in the future. Suggestions include reconnection to the floodplain through removal of embankments in the upper catchment as well as better land management through leaky bunds and buffer strips (Figure 2-4).

The key sub catchments where NFM could influence the flood risk within Inverurie and Port Elphinstone is on the Ton Burn. This is due to the Ton Burn being one of the key tributaries on to the River Don, providing a large volume of flow due to a sizeable catchment.

5.4.7 Planning policy

Scottish Planning Policy and accompanying Planning Advice Notes set out Scottish Ministers' priorities for the operation of the planning system and for the development and use of land. In terms of flood risk management, the policy supports a catchment-scale approach to sustainable flood risk management and aims to build the resilience of our cities and towns, encourage sustainable land management in our rural areas, and to address the long-term vulnerability of parts of our coasts and islands. Under this approach, new development in areas with medium to high likelihood of flooding should be avoided[9].

9 North East Local Plan District - Local Flood Risk Management Plan Inverurie and Kintore, Aberdeenshire Council, https://www.aberdeenshire.gov.uk/media/17360/pva-06_13-inverurie-and-kintore.pdf

5.5 Long list of options

The following tables provide an overview of potential flood alleviation options targeting flood risk from the two watercourses in Inverurie and Port Elphinstone. The tables have been derived using the non-exhaustive long list options from SEPAs guidance[10]. These have been separated into two different design areas based on source and mechanisms of flood risk. Figure 5-2 below shows the different design areas, the Do Minimum 0.5% AP (200 year) + climate change event has been used to show the flood risk to these areas.

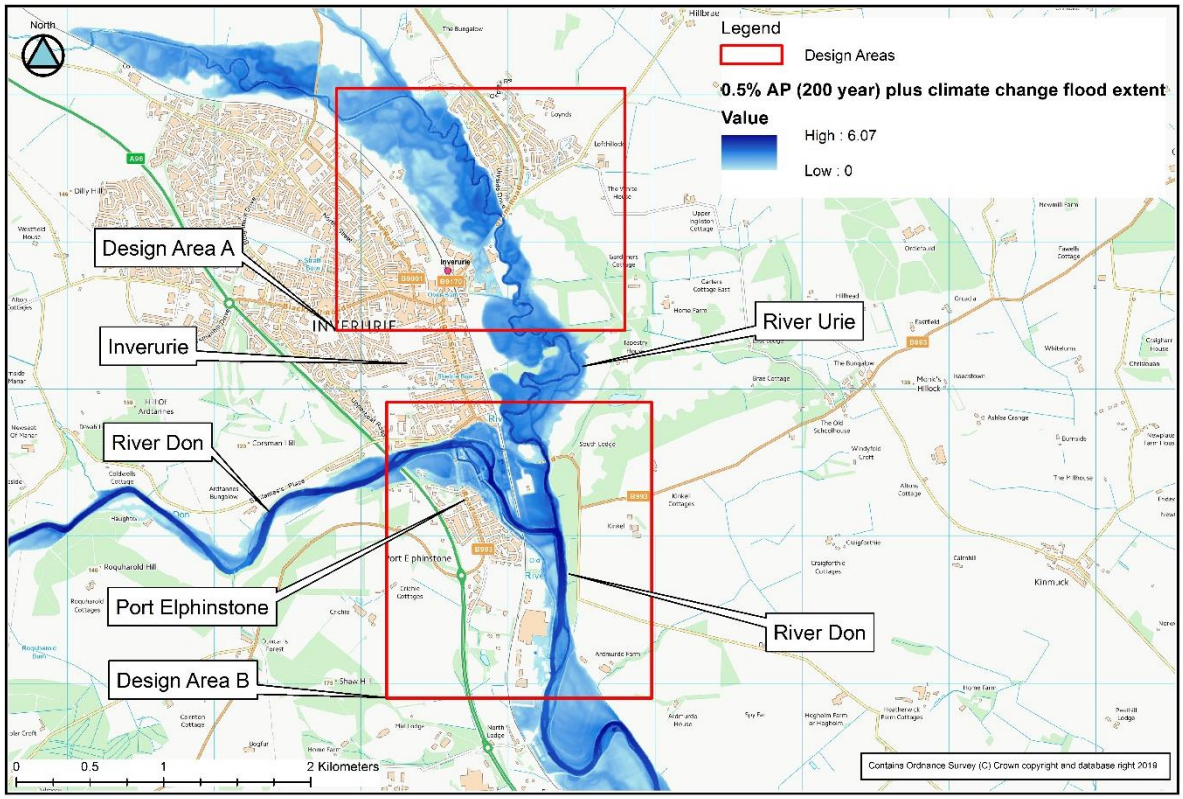


Figure 5-2: Inverurie and Port Elphinstone Design Areas

The areas were selected as they each have different mechanisms which lead to flooding as follows:

- **Design area A (Oldmeldrum Road)** - This location is subject to flooding from the River Urie and is focussed around the flood risk over Oldmeldrum Road.
- **Design area B (Port Elphinstone)** - This location is subject to flooding primarily from the River Don though has some influence from the River Urie focussing on the flood risk to the properties in Port Elphinstone and around Keithhall Road.

10 Local Authority flood study checklist, Flood Risk Management (Scotland) Act 2009 (FRM Act), Version 3, 10 September 2018

Table 5-2: Long list of options for design area A (Oldmeldrum Road)

Area A - Oldmeldrum Road	
Measure	**Discussion**
Relocation	**Technical:** Relocation or abandonment of properties not politically or socially viable. Well developed community. Option not cost effective as purchase costs will be same as or greater than capped damages. Though relocation is not viable, the land use planning system should encourage locations such as Souterford Industrial Park to move towards less flood sensitive usage as part of normal business turnover. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS **Decision: Option discounted**
Flood warning	**Technical:** Flood warning is currently in place for Inverurie and Port Elphinstone, this should be maintained to aid other options. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** No constraints. **Decision: Option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Property level protection and resilience will benefit the site but may need to be implemented with another method, where all properties currently have access to products, including a limited number of sandbags. Many properties draw close to the flood depth of 600 mm recommended as a maximum for property resistance measures. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600 mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. Many properties are above the 600 mm threshold. **Decision: Option reviewed in section 5.6.4**
Local planning policies	**Technical:** Must comply with local plans such as the Scottish Planning Policy (SPP), local authority development plans, any conservation areas. Uryside Park between the B9001 and Oldmeldrum Road Bridge has been reserved for a park where construction of paths and other features are already underway. Downstream of Oldmeldrum Road has been safeguarded for employment use. These locations will have to be considered with all other options. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** The indicated locations should be avoided for development. **Decision: No decision as a standalone option though should be considered alongside all other options**
Runoff (NFM)	**Technical:** Good land management practices such as implementation of buffer strips and riparian planting has been recommended throughout the catchment. **Environmental:** Good land management will result in better water quality as well as the potential for new habitat creation for example from hedgerows and buffer strips. **Constraints:** Would require land owner buy in and effective consultation. **Decision: Option taken forward alongside other options**

Area A - Oldmeldrum Road	
River/floodplain restoration (NFM)	**Technical:** Floodplain restoration has been identified on the Urie through offline ponds, removal of an embankment meander and wetlands. **Environmental:** RBMP benefits of embankment removal reconnecting the channel to the floodplain. Offline ponds and wetlands will improve wildlife diversity in the area. Potential to damage wildlife habitats in the watercourse corridor during construction. **Constraints:** Would require land owner buy in and effective consultation. **Decision: Option taken forward alongside other options**
Sediment management (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and hence blockage of structures over time. **Environmental:** Good land management such as hedgerows, buffer strips and leaky bunds will result in better water quality, including a reduction of diffuse pollution, as well as the potential for new habitat creation. **Constraints:** Would require land owner buy in and effective consultation. **Decision: Option taken forward alongside other options**
Storage	**Technical:** The River Urie already has an extremely strong connection to its floodplain therefore significant engineering would be required to obtain any additional volume where substantial volume would be required. Properties are scattered throughout the entire reach close to the watercourse therefore it is extremely unlikely anywhere on the River Urie could be used for either online or offline storage. In particular there is unlikely to be any location big enough for the volumes using offline storage. As per discussion with stakeholders redesign of B9001 bridge could provide a slight addition of storage which may be enough to prevent the overtopping of Oldmeldrum Road. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. Blocking the channel with online storage is likely to have large negative environmental impacts on fish migration. **Constraints:** Existing connection to the floodplain already uses a substantial amount of storage. Properties scattered throughout the catchment close to the watercourse limiting any raise in levels. **Decision: B9001 redesign for storage to be reviewed in Section 5.6**
Channel modification	**Technical:** Technically viable in the form of deepening and straightening though a large amount of out of bank flooding would require a large increase in conveyance on an already naturalised channel. **Environmental:** Alteration to the naturally winding channel will have negative RBMP implications. **Constraints:** Large volumes required therefore unlikely to be financially viable. **Decision: Option discounted**
Channel diversion	**Technical:** A diversion channel or an "overflow" channel is feasible on the wide floodplain upstream of Oldmeldrum Road, though due to the natural meandering of the channel a diversion channel would likely increase velocity and cause the same flood risk at Oldmeldrum Road. **Environmental:** Potential to create new habitats. Negative impact on sediment transport due to dual flow paths created.

Area A - Oldmeldrum Road	
	Constraints: Designated area for park and green space with construction of footpaths and tree planting already completed. **Decision:** **Option discounted**
Channel realignment	**Technical:** Due to the channel being naturally meandering it is likely that realignment would have a detrimental impact from increased velocity. However, there are a few sections of straightened channel within area A which could be made more sinuous, slightly improving flood risk downstream. This slight increase could help with future increase in flows. **Environmental:** Realigning a naturally meandering channel will have negative RBMP implications. More sinuous channel will aid morphological pressures **Constraints:** Considerable environmental impacts, unlikely to reduce flood risk **Decision:** **Option recommended as a potential solution to help with increased flow from climate change**
Structure modification	**Technical:** Modification to the opening of Oldmeldrum Road bridge is viable either by increasing the inlet size or raising the road and adding additional culverted openings on the floodplain. **Environmental:** Disturbance to wildlife likely during construction. **Constraints:** Increased volume through the structure may have detrimental effects downstream. **Decision:** **Option discussed further in Section 5.6.2**
Control structures	**Technical:** There is a weir in the channel upstream of the design area at Milton of Inveramsay. removal of this structure is likely to increase flows downstream therefore it would not reduce flood risk to the study area, only having the capability to increase flood risk to the study area. Though the structure is also a great distance upstream, removal will unlikely affect the study area as the increase in flow will likely dissipate by the time it reaches Area A. Removal should not be taken forward. Any new control structures are likely to cause flood risk to other properties due to a rise in level behind the structure. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Likely to cause flood risk upstream. Land ownership constraints. **Decision:** **Option discounted**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. A direct defence along the upstream face of the road could defend the properties at risk, it could also be incorporated with raising of the road. **Environmental:** Due to the substantial offset of the defences from the channel no significant environmental or RBMP impacts are observed from this option. **Constraints:** The natural floodplain Uryside Park would need to be reviewed as to whether any detrimental effect to upstream properties would occur. Local plan will need to be reviewed as this area is designated to park space though a direct defence is unlikely to significantly impact on the area. **Decision:** **Option taken forward**
Watercourse maintenance	**Technical:** As the Urie is a large channel watercourse maintenance would not be viable as a sole solution though is good practice to prevent any coarse obstructions at structures. Watercourse maintenance shall take the form of clearance of blockages along the watercourse and structures. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant.

Area A - Oldmeldrum Road	
	Constraints: No significant constraints **Decision:** **Option taken forward alongside other options**
Self help	**Technical:** Self help could be used in conjunction with other methods of prevention. More awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision:** **Option taken forward alongside other options**
Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** No significant constraints **Decision:** **Option taken forward alongside other options**

Table 5-3: Long list of options for design area B (Port Elphinstone)

Area B - Port Elphinstone	
Measure	**Discussion**
Relocation	**Technical:** Relocation or abandonment of properties not politically or socially viable. Well developed community. Option not cost effective as purchase costs will be same as or greater than capped damages. Though relocation is not viable, the land use planning system should encourage locations such as Kirkwood Commercial Park to move towards less flood sensitive usage as part of normal business turnover. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS **Decision: Option discounted**
Flood warning	**Technical:** Flood warning is currently in place for Inverurie and Port Elphinstone, this should be maintained to aid other options. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** No significant constraints **Decision: Option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Property level protection and resilience will benefit the site but may need to be implemented with another method, where all properties currently have access to products, including a limited number of sandbags. Many properties draw close to the flood depth of 600 mm recommended as a maximum for property resistance measures. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600 mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. Many properties are above the 600 mm threshold. **Decision: Option reviewed in section 5.6.4**
Local planning policies	**Technical:** Must comply with local plans such as the Scottish Planning Policy (SPP), local authority development plans, any conservation areas. Multiple historic protected areas within the town itself. Upstream of the A96 road bridge has a large designation for housing development. Davidson Field has been designated at protected area to conserve the playing field. The greenspace on the outside meander next to the Scottish Water embankment has been designated a protected greenspace. The right bank of the Don at Kirkwood Commercial Park is a designated area for businesses. These locations will have to be considered with all other options. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** The indicated locations should be avoided for development though there is opportunities to help retain greenspace through a formalised scheme. **Decision: No decision as a standalone option though should be considered alongside all other options**
Runoff (NFM)	**Technical:** Good land management practices such as implementation of buffer strips and riparian/hedgerow/gully planting has been recommended throughout the catchment. **Environmental:** Good land management will result in better water quality as well as the potential for new habitat creation for example

Area B - Port Elphinstone	
	from hedgerows and buffer strips. **Constraints:** Would require land owner buy in and effective consultation. **Decision:** **Option taken forward alongside other options**
River/floodplain restoration (NFM)	**Technical:** Some embankment removal in the upper catchment could help store more flood water on the floodplain. The embankments in Inverurie could be set back further from the channel to give additional out of bank storage on the natural floodplain. **Environmental:** RBMP benefits of embankment removal reconnecting the channel to the floodplain. **Constraints:** Local planning for greenspace behind the embankments will require consultation if they are to be set back from the channel. **Decision:** **Option taken forward alongside other options**
Sediment management (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and hence blockage of structures over time. **Environmental:** Good land management such as hedgerows, buffer strips and leaky bunds will result in better water quality as well as the potential for new habitat creation. **Constraints:** Would require land owner buy in and effective consultation. **Constraints:** No significant constraint **Decision:** **Option taken forward alongside other options**
Storage	**Technical:** The River Don has extremely large volumes therefore a large area would be required to store enough volume to protect the properties in Inverurie and Port Elphinstone. Any storage area upstream of Kemnay is unlikely to influence the study area as it will no longer capture enough tributary flows, in particular from the large Ton Burn. The area in between Kemnay and Inverurie has multiple scattered properties along the watercourse therefore a storage area in this location would not be able to hold enough volume. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. Blocking the channel with online storage is likely to have large environmental impacts on fish migration. **Constraints:** Properties scattered throughout the catchment close to the watercourse limiting any raise in levels. Substantial area would be required to store large volumes. **Decision:** **Option discounted**
Channel modification	**Technical:** Technically viable particularly through the removal of the islands between the Don and the Canal though it is unlikely to provide enough conveyance and be a sustainable solution. **Environmental:** Well established islands, continual removal of sedimentation in the channel will disturb habitats. **Constraints:** Large volumes required therefore unlikely to be financially viable due to non-sustainable solution. **Decision:** **Option discounted**
Channel diversion	**Technical:** The area at risk is fully constrained by properties therefore there is no room for a diversion channel, a diversion channel upstream and downstream would have a negligible effect on the area at risk. **Environmental:** No significant environmental impact. **Constraints:** No significant constraints. **Decision:** **Option discounted**

Area B - Port Elphinstone	
Channel realignment	**Technical:** The area at risk is fully constrained by properties therefore there is no room for channel realignment. **Environmental:** No significant environmental impact **Constraints:** No significant constraints **Decision:** **Option discounted**
Structure modification	**Technical:** On the Don and Urie the structures affecting the flood risk are located on the Don and are extremely large and not at full capacity therefore modification would not reduce the flood extent. The structures on the Canal could be removed as they are no longer required other than the rail bridge, the channel could also be deepened here to increase conveyance for lower events. **Environmental:** No significant environmental or RBMP benefits. Could be benefit safer access to the area for recreational use. **Constraints:** May be some minor social constraint due to residents using the bridges for walking, public engagement required. **Decision:** **Canal structures removal taken forward**
Control structures	**Technical:** Any new control structures are likely to cause flood risk to other properties due to a rise in level behind the structure. Removal of the weir at the canal outlet may reduce flood risk particularly around the outlet. **Environmental:** Ecological benefit for fish migration if weir were removed. **Constraints:** May have detrimental implications on properties downstream. **Decision:** **Control structure removal taken forward**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. Modification to the existing embankments at Davidson Field and Scottish Water could reduce the flood risk. A direct defence could also protect the properties at the Canal outlet. A direct defence is likely to also be required to prevent flow through Keithhall Road from the Urie. **Environmental:** Continued use of embankments close to the channel will have a negative RBMP impact. Re-design of the embankments further from the channel would reconnect the channel to the natural floodplain. **Constraints:** Direct defences on the Urie may have a detrimental effect downstream due to reduced storage on the floodplain. **Decision:** **Option taken forward**
Watercourse maintenance	**Technical:** As the Don is a large channel watercourse maintenance would not be viable as a sole solution though is good practice to prevent any coarse obstructions at structures. Particularly around the central piers upstream of the canal. Watercourse maintenance shall take the form of clearance of blockages along the watercourse and structures. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. **Constraints:** No constraints. **Decision:** **Option taken forward alongside other options**
Self help	**Technical:** Self help could be used in conjunction with other methods including more awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision:** **Option taken forward alongside other options**

Area B - Port Elphinstone	
Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** No significant constraints **Decision:** **Option taken forward alongside other options**

5.6 Feasibility Study

5.6.1 River Urie Storage

Though the River Urie has a good connection with its floodplain there is still potential for additional storage in particular this could be achieved using the B9001 Howford road bridge (asset No.2 as per Asset condition assessment)[11]. This section was highlighted by the stakeholders as the bridge may be redesigned in the future, therefore it could take into account storage of more flow behind it and hence be designed as an outflow structure. Figure 5-3 below shows how this structure could be designed and includes results from the 0.5% AP (200 year) plus climate change run when reducing the bridge by almost 66% from 61.4m^2 to 20.3m^2.

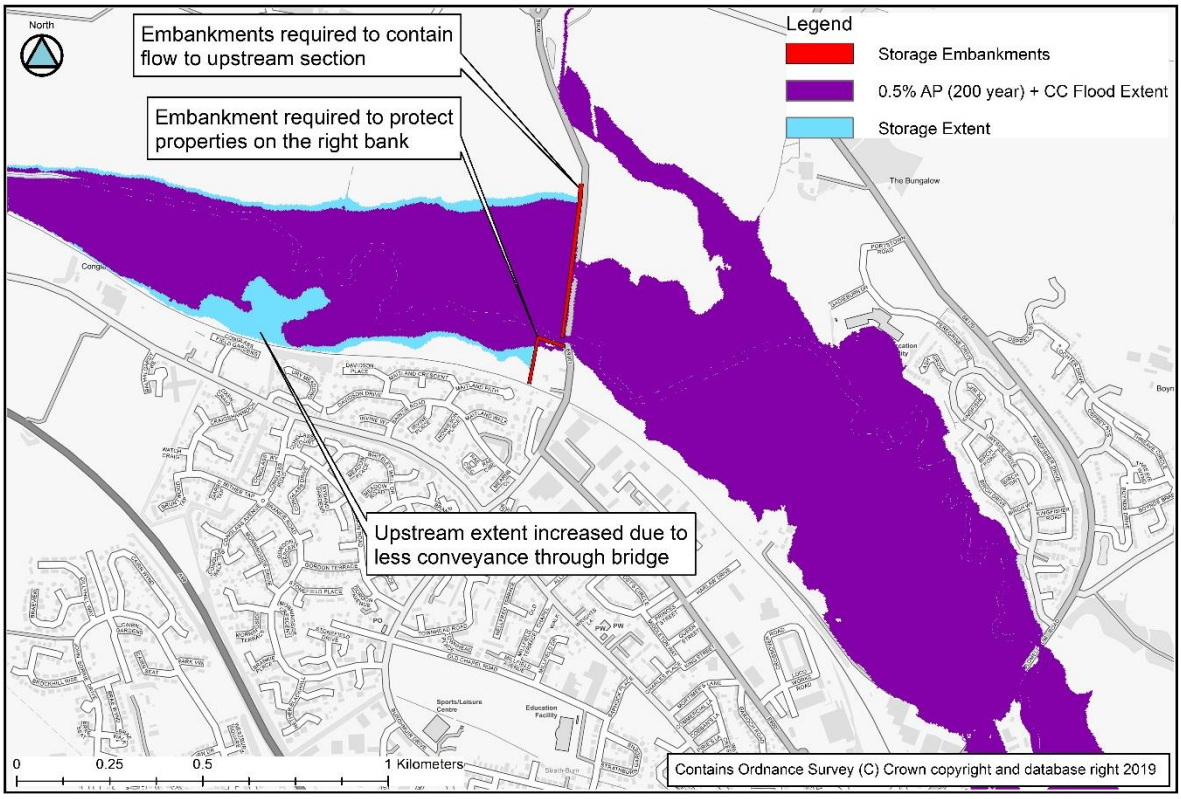


Figure 5-3: Upstream storage extent

11 Inverurie Asset Condition Assessment, JBA Consulting, 04 May 2018

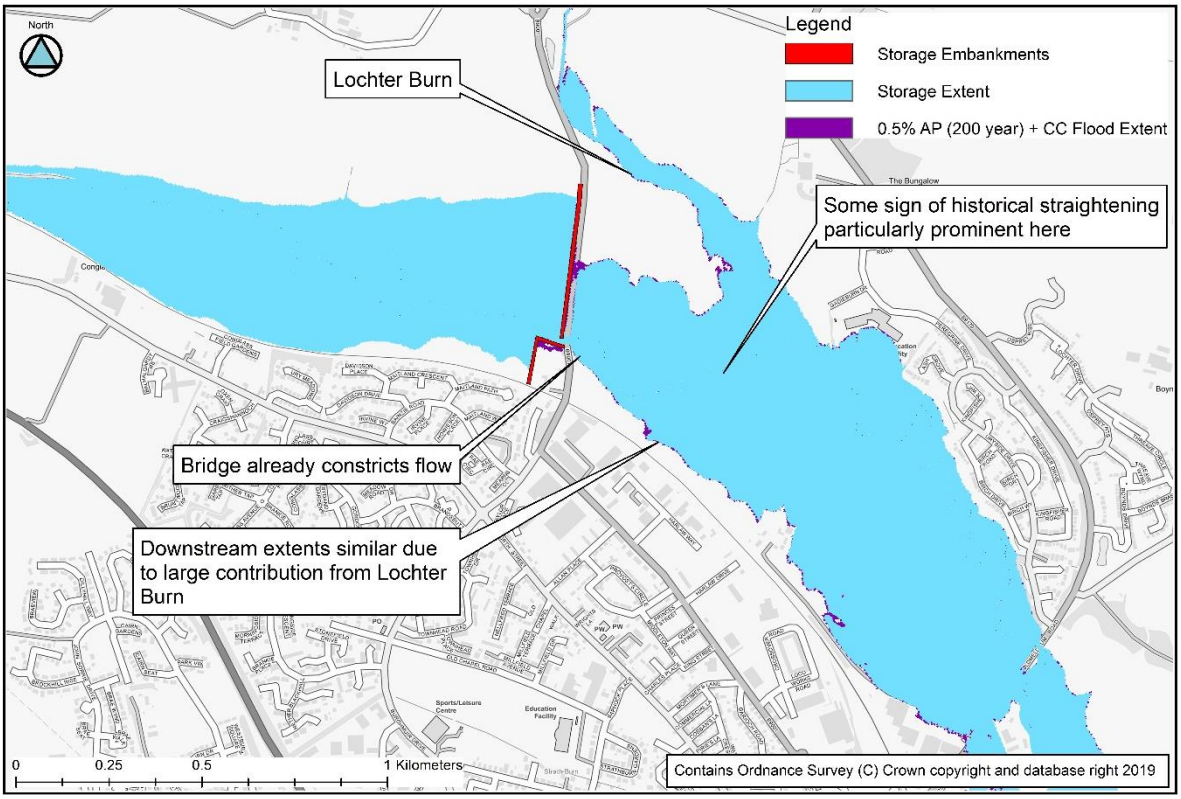


Figure 5-4: Downstream storage extent

Figure 5-3 and Figure 5-4 show that the use of storage in this location has a negligible impact downstream. The bridge opening currently conveys a flow of around 165 m^3/s where water does not reach the bridge soffit. The constriction put in place raises the stage by around 3 m upstream though only reduces the flow through the bridge by 10 m^3/s. This is due to even with the bridge opening reduced it still has an area of 20 m^2 which does not significantly constrict the flow. At the rate of stage gain per reduction in conveyance it would not be economically viable to find a solution due to the resulting embankment heights which already require a height of approximately 3.5 m at the properties on the right bank with the current constriction. The Lochter Burn also contributes a reasonable amount of flow downstream of the bridge, contributing to the flood risk, having a catchment size of 65km^2 equating to a peak flow value of 49 m^3/s. Due to the lack of change in levels downstream of the structure storage on the River Urie has been discounted.

5.6.2 Souterford Bridge conveyance

Additional conveyance through the Souterford road bridge B9170 (asset No.4 as per Asset condition assessment)[12] on the River Urie could allow more water to pass downstream preventing the overtopping of the road at this section. This was tested by simulating an overflow pipe under the road by removing 70 m of the embankment on the floodplain. The arrangement and results of this option are shown in Figure 5-5 below.

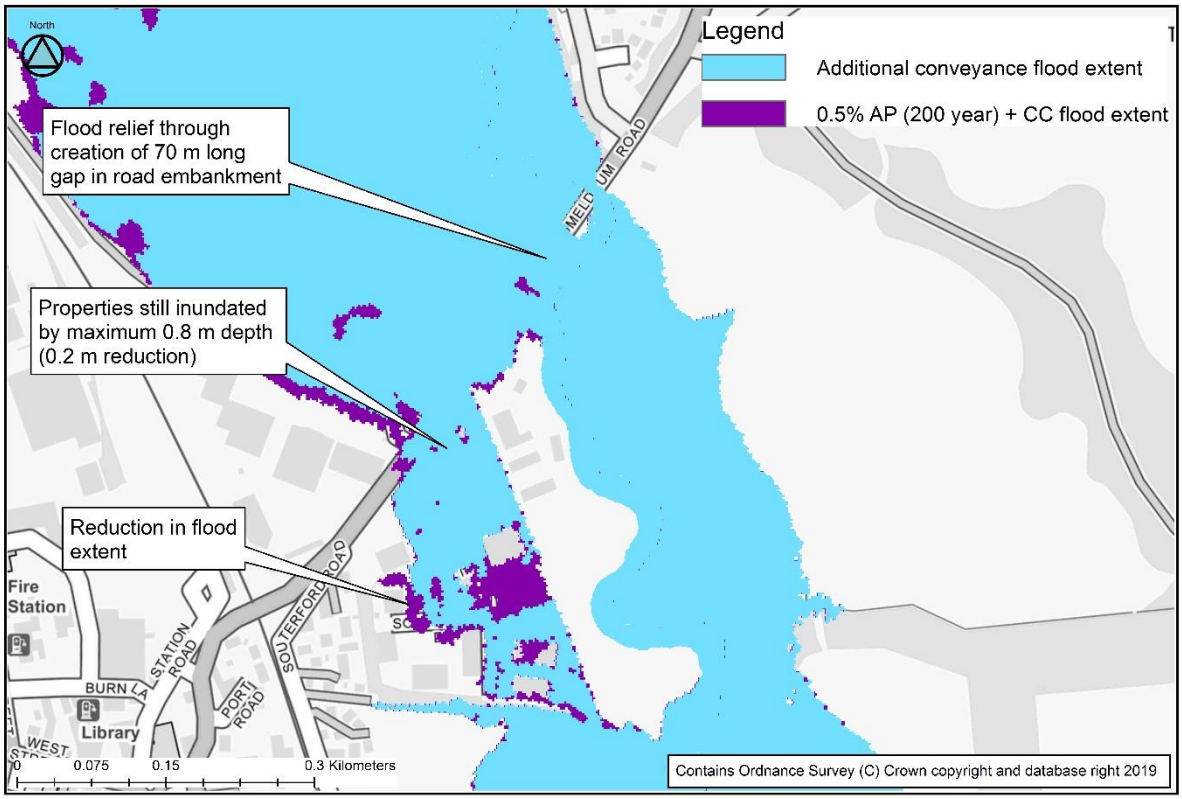


Figure 5-5: Oldmeldrum conveyance increase

Figure 5-5 shows the additional conveyance through the embankment slightly reduces the flood extent downstream though does not significantly reduce the flood depths. The properties which are most at risk are the ones adjacent to the road which still incur flood depths up to 0.8 m. An additional 70 m opening is substantial, therefore if this option were to be taken forward it would require a significant and unfeasible amount of engineering, particularly in comparison to the option of an embankment in the area. If this option were to be taken forward it is unlikely that it could be considered as a standalone option, it would require additional embankments or road raising. Further, allowing even more flow to pass through would also require more investigation into the influence on downstream flood risk.

12 Inverurie Asset Condition Assessment, JBA Consulting, 04 May 2018

5.6.3 Embankment Alignment

The embankment positioning around design area B (Port Elphinstone and South Inverurie) has been evaluated to optimise the area as far as possible therefore other alignments have been tested and discounted from further consideration. The most optimal alignment is shown in Figure 5-6, the critical decision points are numbered and discussed further below.

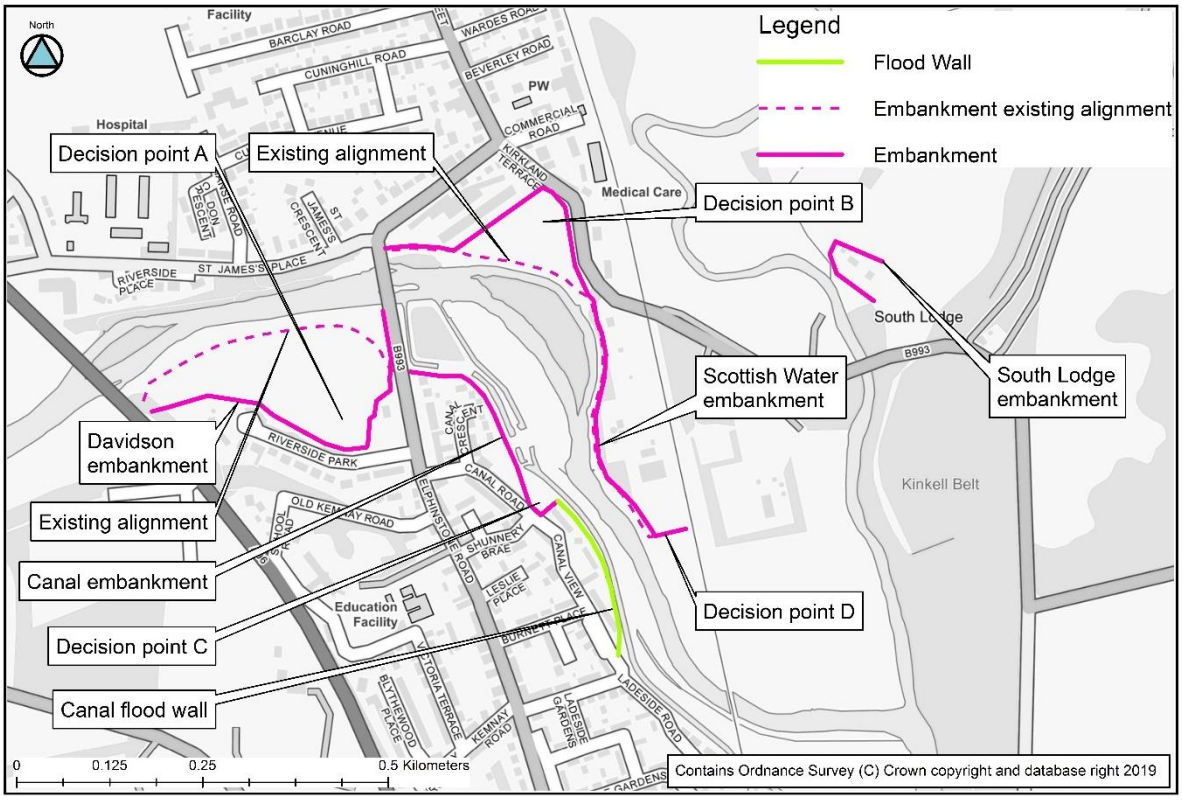


Figure 5-6: Embankment decisions

The alignment has been determined by concluding the following on each decision point shown in Figure 5-6 above:

- Decision point A - Davidson embankment has been set back to the other side of the field in order to reconnect more of the river with its floodplain. This will allow for more storage while retaining and formalising the green space designated for sports pitches.
- Decision point B - As with Davidson embankment the Scottish Water embankment has also been set back further to allow the river to have more of a connection to its floodplain while increasing storage. This will also help formalise the area as a green space.
- Decision point C - The area within point C contains a structure which has been identified as a substation. The substation is currently being allowed to flood in order to set back the embankment as far as possible. This should be investigated and if the substation should not be on the floodplain the embankment should be moved to run along the bank.
- Decision point D - The Scottish Water embankment currently runs to the railway line along the bank. In order to maximise floodplain storage and reduce costing of a new embankment this has been clipped at point D which is currently unused land other than an unadopted track from the Scottish Water Treatment Works to the railway line.

As well as the alignments of the embankments above further analysis will be conducted on the following:

- The existing alignment of the Davidson and Scottish Water embankments will be appraised as an option to determine the most socially and economically viable solution.
- A potential future option where within the 100 year appraisal period the older Scottish Water treatment works west of the rail embankment is assumed to be demolished and hence unprotected, dramatically reducing the embankment length required.

5.6.4 Property Level Protection (PLP)

PLP within both design areas is largely an unacceptable solution. This is primarily due to the large number of properties predicted to flood at depths greater than the 0.6 m threshold during the Do Minimum scenario as shown in Table 5-4 below for both the 0.5% AP (200 year) event and the same event plus climate change.

Table 5-4: Property Level Protection feasibility

Annual Probability [AP] (%)	Return Period (years)	Number of Properties < 0.6 m flood depth (PLP viable)	Number of Properties > 0.6 m flood depth (PLP not viable)
0.5	200	74	64
0.5 +CC	200 +CC	28	110

The table shows that if PLP was implemented as a solution many properties would be unprotected during the design events due to PLP failing above a threshold of 0.6 m. As well as this the properties in design area A are factories which require bespoke and expensive PLP making them far more expensive and complicated to install, this is discussed further in Section 5.8.1.3.

5.7 Short list of options

Watercourse maintenance and NFM shall be implemented to some extent with all short-listed options. Following the consideration of the long list and feasibility in Sections 5.5 and 5.6 above, the following options have been shortlisted:

- Design area A (Oldmeldrum Road)
    - Direct defences;
        - Along Oldmeldrum Road around the retail park.
        - Road raising of Oldmeldrum Road.
        - Around the "Gaulds Gas" properties on the floodplain.

- Design area B (South Inverurie and Port Elphinstone)
    - Removal of some of the structures crossing the canal.
    - Alterations to embankments at Davidson Field and Scottish Water treatment works, both in offset positions and existing positions.
    - Embankment and walls on right bank of the canal.
    - Embankment around properties at South Lodge.
    - Flood gate or similar mechanism on Keithhall Road under the railway bridge.
    - Modification around canal outlet;
        - Removal of canal weir outlet.
        - Embankments around canal outlet.

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

5.7.1 Designing for climate change

In line with Scottish Planning Policy a 0.5% AP (200 year) standard of protection for any scheme was the goal throughout the short listing process. 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 24% increase in the peak river flow.

Where a 0.5% AP (200 year) standard is not feasible interventions will be considered 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 will be

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.

5.8 Flood mitigation options - design areas

The following section details the constraints and benefits of the shortlisted options for Inverurie and Port Elphinstone. This has initially been analysed within the two design areas separately in order to conclude the most feasible option in each area. These will then be combined to find the most viable solution for Inverurie and Port Elphinstone as a whole.

5.8.1 Design area A - Oldmeldrum Road flow paths

In order to protect against the 0.5% AP (200 year) event plus climate change at Oldmeldrum Road the pathway flowing south east into the industrial estate needs to be resolved. Flooding commences at the 1.33% AP (75 year) due to overtopping of the road. In order to protect against this flow pathway water either needs to be held back on the floodplain behind the road or more water needs to be conveyed through the bridge opening and under the road taking any detrimental effects to other properties into consideration both upstream and downstream.

Figure 5-7 shows the pathway which causes flood risk to the road and properties downstream of the bridge during the Do Minimum 0.5% AP (200 year) event plus climate change.

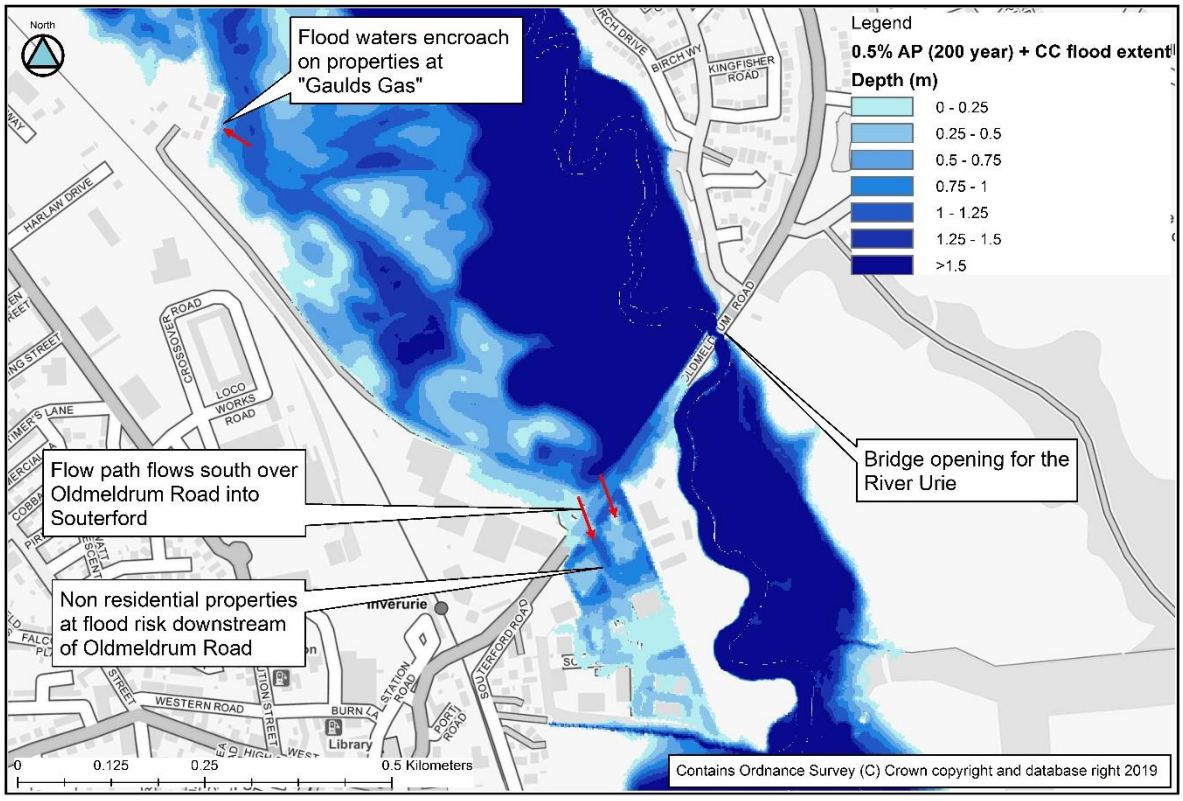


Figure 5-7: Flow pathway within design area A - Oldmeldrum Road

Option A1a* and A1b*:
Direct defence upstream of Oldmeldrum Road

*Each option is followed by an "a" or "b" signifying if it is defending against the 0.5% AP (200 year) event with the allowance for climate change or the 0.5% AP (200 year) event.

a = 0.5% AP (200 year) plus climate change

b = 0.5% AP (200 year)

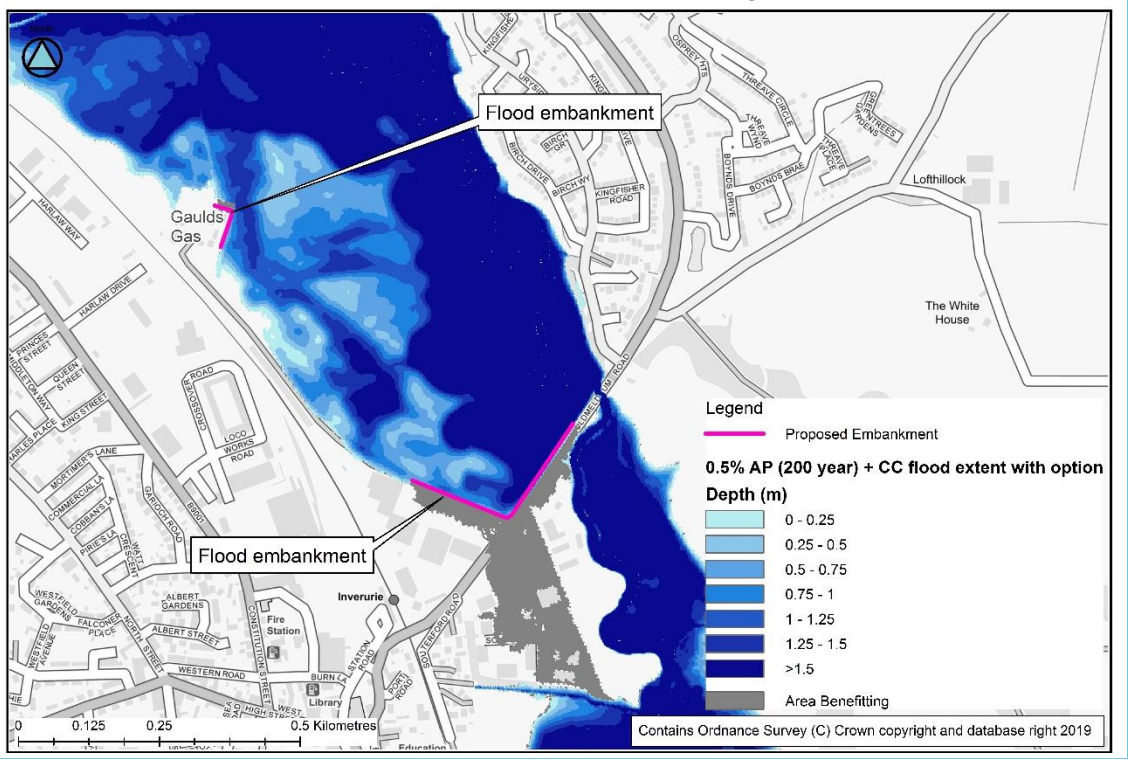
5.8.1.1 Option A1a - Direct defence upstream of Oldmeldrum Road designed to the 0.5% AP (200 year) plus climate change

Option A1a - Direct defence upstream of Oldmeldrum Road

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of an embankment at Oldmeldrum Road. A small embankment is also required for the properties on the floodplain due to detrimental effect from holding back the water. The work includes the following:

- Install a flood embankment along Oldmeldrum Road and the commercial park in the south-east corner of the floodplain for a distance of approximately 385 m. The maximum embankment height will be 3.76 m (from the floodplain) with an embankment defence level of 56.64 mAOD including a 0.6 m freeboard. The road level varies around 55 - 56 mAOD.
- Install a flood embankment around the properties at Gaulds Gas, Uryside on the floodplain for a distance of approximately 101 m. The maximum embankment height will be 1.43 m with an embankment defence level of 56.68 mAOD including a 0.6 m freeboard.



Standard of Protection (SOP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 144 m^3/s at the Pitcaple gauging station.

Alternative quick wins / Preliminary investigations

It was made apparent from the storage feasibility test, Figure 5-4, that the Lochter Burn helps to contribute some of the flow at this location. NFM on this watercourse could reduce the flood risk to the area. It was identified on the NFM site walkover that embankment removal, creating more natural meanders, planting woodland and creating wetlands are all achievable on the Lochter Burn.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated. Due to lack of GI information a cut-off assumption of 0.5 m depth has been made, the cut-off depth will require further investigation at detailed design.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for both embankments: Use of public roads, unlikely closure will be required.

Waste

- Expected quantity of waste material for embankments: 4,171 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stock piles of soil and non-toxic spoil and construction waste should be located outside the functional floodplain (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.

Proximity of defence to other structures

- Private and Public: Public footpath over the floodplain. Public roads adjacent to both embankments.
- Houses: Properties are in close proximity to the smaller embankment on the floodplain.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- Consultation required with SNH and SEPA.
- Construction of the embankment also prevents flood water from breaching the land where a recycling centre is in use, this would prevent pollution from this site potentially reaching the River Urie.
- Many Invasive Non Native Species (INNS) have been identified by NESBReC within the study area including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and Rhododendron. The field survey conducted by JBA primarily identified Giant Hogweed and Himalayan Balsam along the banks of the River Urie. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction.

Health and safety hazards noted

Works near to public areas.

Social and community issues

Some aesthetic issues as this option will require large embankments alongside Oldmeldrum Road, though the height is far higher from the floodplain the majority of users will be on Oldmeldrum Road itself.

The floodplain has been developed into a "riverside park" where the embankment will cut-off the pathed entrance. An allowance for redesign of the path around the embankment should be investigated.

The properties on the floodplain may not have previously flooded therefore holding back the water to the point where a flood defence is required in their area will require further consultation with residents at this location.

Impact on other reaches

The works may affect the Lochter Burn due to the downstream boundary of this burn being influenced by the water in the Urie. This influence is negligible due to very minor depth increases where using the 0.5% AP (200 year) plus climate change event showed the water level increasing from 56.017 m to 56.118 m when the option was tested in the model.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- Removing the flow path into the industrial park may add more pressure through Souterford Bridge as the only flow path remaining downstream. Reviewing the model, the option increases the water level by 0.08 m. As the bridge is already overtopped and the option does not increase the water level greatly it is unlikely the risk of scour or structural failure will increase however erosion was witnessed during the 2016 event therefore it is recommended a scour assessment is carried out on the bridge at detailed design. NFM or overland culverts may be required to reduce this risk.
- Authorisation from SEPA may be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

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

Consider constructing embankments so that they may be adapted in the future due to increased flows from climate change.

Consideration to create a more sinuous corridor where natural straightening has occurred upstream and downstream of the B9001 road bridge. Along with removal of the informal embankments here, velocities may slow improving flood risk downstream and improving the morphological conditions.

5.8.1.2 Option A1b - Direct defence upstream of Oldmeldrum Road designed to the 0.5% AP (200 year)

Option A1b - Direct defence upstream of Oldmeldrum Road

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of an embankment at Oldmeldrum Road. A small embankment is also required for the properties on the floodplain due to detrimental effect from holding back the water. All aspects of this option are identical to option A1a other than the embankment properties at Oldmeldrum Road which are as follows:

- Install a flood embankment along Oldmeldrum Road and the commercial park in the south-east corner of the floodplain for a distance of approximately 385 m. The maximum embankment height will be 3.38 m (from the floodplain) with an embankment defence level of 56.26 mAOD including a 0.6 m freeboard. The road level varies around 55 - 56 mAOD.

The properties on the floodplain are not at risk during the 0.5% AP (200 year) event though as they have been identified at risk due to the detrimental effect of the option when climate change is added the embankment will remain the same for this option as it was for option A1a.

5.8.1.3 Area A discussion

Area A includes 6 non-residential properties which flood during the 0.5% AP (200 year) event plus climate change and 2 non-residential properties which flood during the 0.5% AP (200 year) event. The most sustainable option is to construct an embankment to prevent the flow path from passing over the road as per the previous options discussed. An initial increase in standard of protection can be achieved by protecting against the 1% AP (100 year) event though the embankment length would remain large to prevent the flow path into Souterford in order to protect 2 properties. Due to this in order to conclude on a more cost effective solution the standard of protection increase has started at 0.5% AP (200 year).

PLP within this area has been discounted, this is due to the majority of the properties at risk being industrial buildings with large custom openings at their threshold. This would require expensive bespoke products which would need to be priced through a full survey of the area.

Due to the reasoning above the following options should be considered for area A:

- Long term option - The long term solution when looking at a full 100 year appraisal period would be hard engineering via an embankment along Oldmeldrum Road.
- Short to mid-term option - The short to mid-term option would be to consider PLP through a further analysis of the area to allocate bespoke products. As well as this it should be consulted with the property owners whether they are content with the residual damages highlighted in this study in the short term where relocation may be considered at some point during the 100 year appraisal period.

5.8.2 Design area B - Port Elphinstone and South Inverurie flow paths

In order to protect against the 0.5% AP (200 year) event plus climate change at Port Elphinstone and South Inverurie a number of different flow paths need to be considered. Figure 5-8 shows the key flow pathways which cause flood risk to the properties within the design area during the 0.5% AP (200 year) event plus climate change.

Flooding commences from the River Don and Urie flowing out of bank during from the 2% AP (50 year) event.

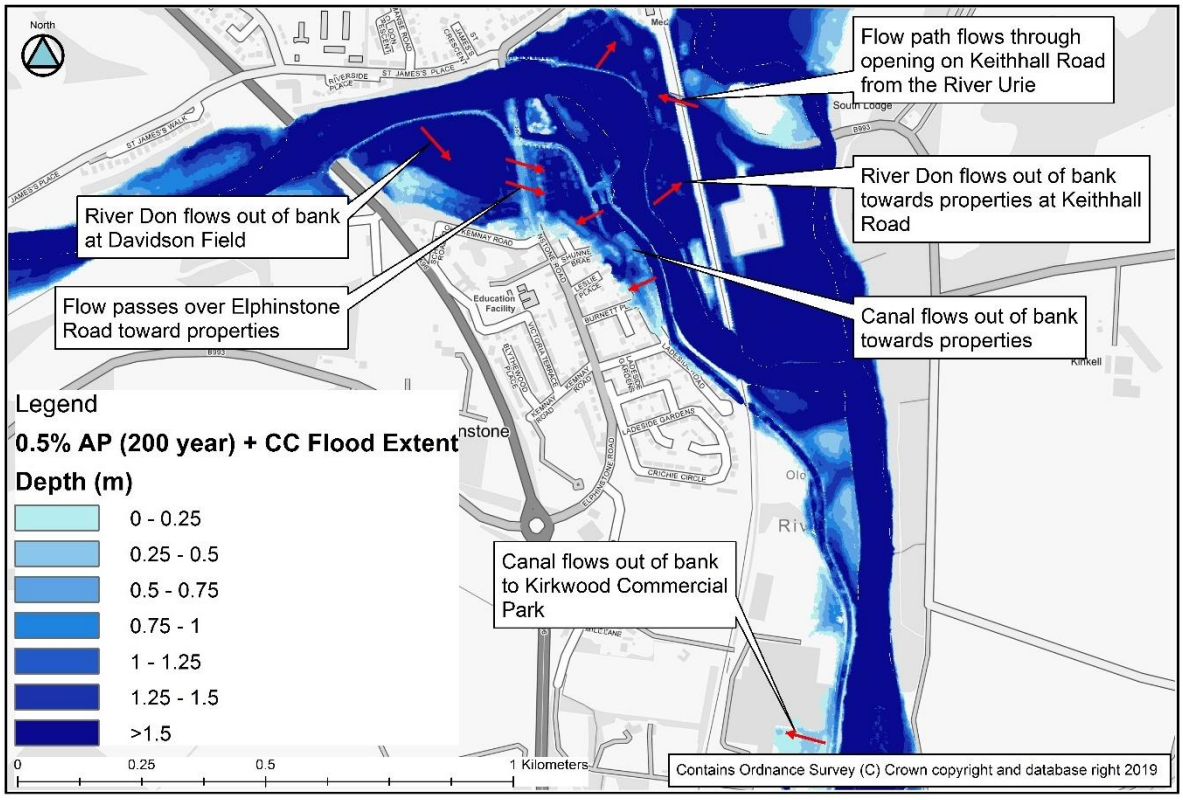
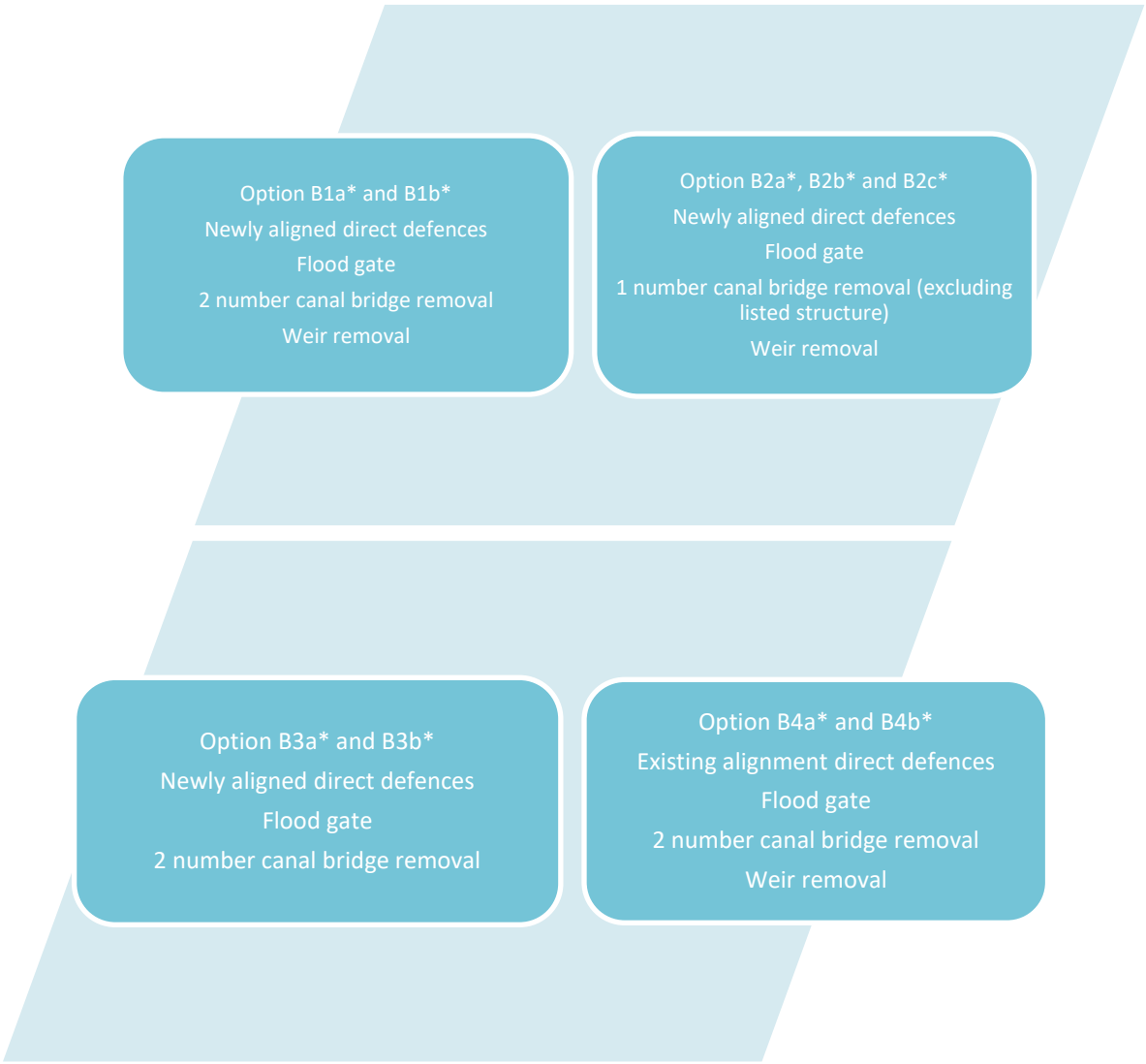


Figure 5-8: Flow paths within design area B - Port Elphinstone and South Inverurie



*Each option is followed by an "a", "b" or "c" signifying if it is defending against the 0.5% AP (200 year) event with the allowance for climate change, the 0.5% AP (200 year) event or the 1% AP (100 year) event.

a = 0.5% AP (200 year) plus climate change

b = 0.5% AP (200 year)

c = 1% AP (100 year)

5.8.2.1 Option B1a - Direct defences, flood gate, canal bridge and weir removal

Option B1a - Direct defences, flood gate, canal bridge and weir removal

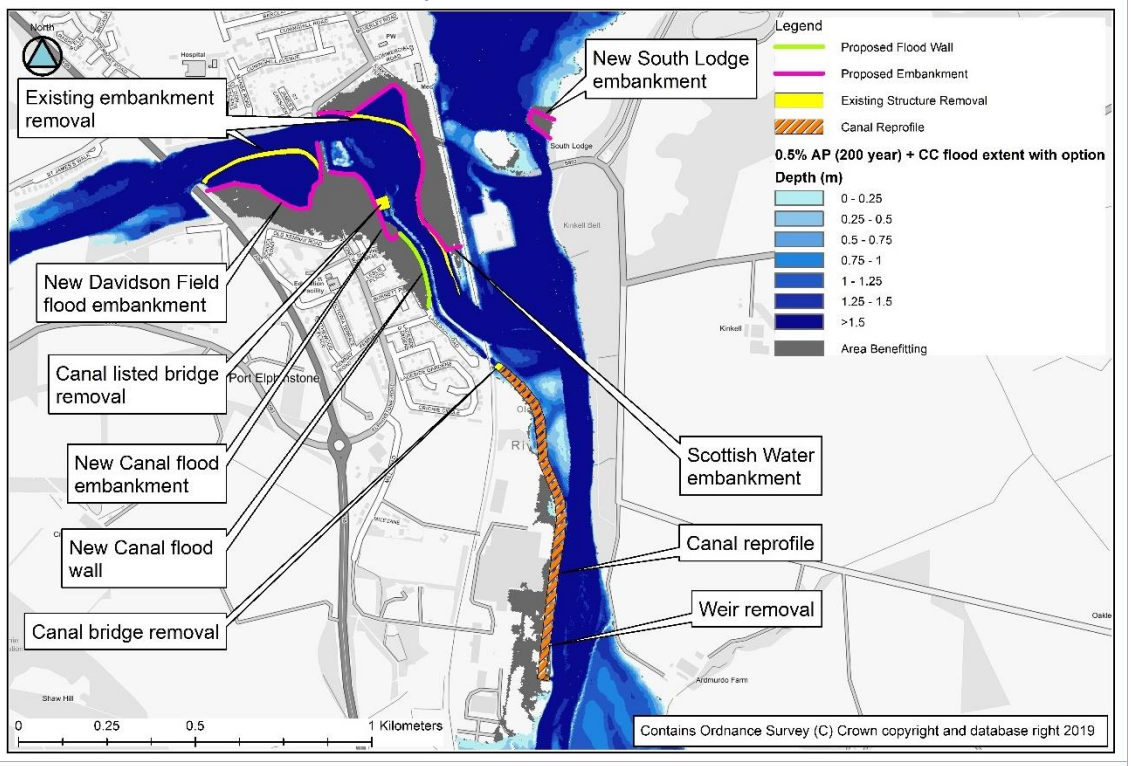
Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of direct defences and existing structure removal. The work includes the following:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.91 m and an embankment defence level of 56.77 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 28.46 m using a 5 m crest and 1 in 3 slopes, there is more than adequate room for this footprint within the park with room for the playing fields. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 2.51 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment

has a maximum height of 3.18 m and an embankment defence level of 55.23 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.08 m using a 5 m crest and 1 in 3 slopes where there is adequate room on the left bank. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.76 m.

- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.41 m and an embankment defence level of 55.48 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 19.46 m using a 5 m crest and 1 in 3 slopes, there is adequate room on the Canal up to where the wall begins.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.36 m and a defence level of 55.18 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 3.28 m and an embankment defence level of 54.90 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.68 m using a 5 m crest and 1 in 3 slopes, there are areas of limited space, particularly around the small watercourse which feeds into the Urie therefore slopes may need to be reassessed at detailed design.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 2.3 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.



Standard of Protection (SOP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 598 m^3/s at Haughton gauging station on the

River Don.

Alternative quick wins / Preliminary investigations

A review and testing of the existing embankments could be conducted to analyse whether they are suitable for an increase in height which would add engineering value to the amount of material wasted and used.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated. Due to lack of GI information a cut-off assumption of 0.5 m depth has been made, the cut-off depth will require further investigation at detailed design.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for Davidson embankment: Use of public and private roads, closure of car park may be required.
- Construction access for Scottish Water embankment: Use of public roads, road closure unlikely. Public footpath around the river may need to be closed.
- Construction access for canal embankment and flood wall: Use of public roads, road closure unlikely, likely closure of public footpath around canal.
- Construction access for South Lodge embankment: Use of public and private roads, road closure unlikely.
- Construction access for flood gates: Use of public roads, likely closure of Keithhall Road during construction.
- Construction access for canal modification: Use of public and private roads, road closure unlikely though public footpath around canal likely to be closed.

Waste

- Expected quantity of waste material for embankment: 22,226 m^3
- Expected quantity of waste material from canal reprofile unknown.
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located outside the functional floodplain (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath close to all direct defences.
- Houses: Canal direct defence in close proximity to properties.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- Consultation required with SNH and SEPA.
- Many Invasive Non Native Species (INNS) have been identified by NESBReC within the study area including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and Rhododendron. The field survey conducted by JBA primarily identified Giant Hogweed and Himalayan Balsam along the

banks of the River Don. It is an offense to spread these INNS therefore control measures should be put in place during construction.

- Morphological and riparian improvement from embankment removal at Davidson Field and, upstream and downstream of the Scottish Water wastewater treatment works.

Health and safety hazards noted

Construction in close proximity to heavily used footpath.

Social and community issues

Some aesthetic issues as this option will require high embankments in a community space though embankments currently exist and are already accepted in this location. Some of the embankments are particularly high which may block views of the watercourses and lower amenity value in the area. The Davidson Field embankment primarily affects the properties at Riverside Park though a line of trees and bushes already exists here which currently restricts views, these should be retained to increase the amenity value of the defence. The Scottish Water embankment does not further constrict the view of any properties as the existing embankment already does so. The Canal direct defences will reduce visibility of the watercourses from the properties, further consultation and acceptance from the property owners may be required in order to prevent objections to the scheme.

Removal of canal bridges will remove a link from the canal bank to the island which is a known footpath therefore construction of a new bridge which does not interfere with the flood water has been incorporated into the scheme.

Consultation will be required with Kirkwood Commercial Park due to modifications on the privately owned canal.

As well as the noted issues there is community benefit from redevelopment of the public access around the canal. A redesign of the access will result in a safer development where there has been at least one fatality due to falling into the canal.

Impact on other reaches

The works may interfere with the River Urie though as the two have been analysed together any detrimental impact has been accounted for.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- Removing the flow path from Davidson Field into Port Elphinstone may add more pressure through the B993 Elphinstone Road bridge as this is the only flow path to downstream remaining. Reviewing the model, the option increases the water level by 0.37 m at the bridge. Due to such a large increase in water level it is recommended a scour assessment is carried out on the bridge at detailed design. Overland culverts may be required to reduce this risk. The water level under current conditions is already above bridge soffit and therefore a detailed scour assessment is advised.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR). In particular a complex CAR license will be likely for the Canal flood wall and CAR authorisation will be required for the demolition and reinstatement of the bridge.
- The hydromorphology impact of the Bruce Crescent embankment would need to be assessed as part of the CAR licence.

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

Consider constructing embankments and walls so that they may be adapted in the future due to increased flows from climate change.

5.8.2.2 Option B1b - Direct defences, flood gate, canal bridge and weir removal

Option B1b - Direct defences, flood gate, canal bridge and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of direct defences and existing structure removal. All aspects of this option are identical to option B1a other than decreases in sizing which are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.31 m and an embankment defence level of 56.18 mAOD including a 0.6 m freeboard. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.92 m. The embankment has a maximum width of 24.86 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.77 m and an embankment defence level of 54.89 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 21.62 m using a 5 m crest and 1 in 3 slopes. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.42 m as per B1a there is adequate space for this footprint.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.03 m and an embankment defence level of 55.12 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17.18 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.00 m and a defence level of 54.82 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.3 Option B2a - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Option B2a - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B2a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length

of 507 m with a maximum height of 3.94 m and an embankment defence level of 56.81 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 28.64 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 2.55 m.

- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 3.24 m and an embankment defence level of 55.35 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.44 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.88 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.08 m and an embankment defence level of 55.17 mAOD including a 0.6 m freeboard.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.05 m and a defence level of 54.87 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 3.28 m and an embankment defence level of 54.90 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.68 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 2.3 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish the footbridge bridge on the Canal directly downstream of the railway bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.4 Option B2b - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Option B2b - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B1a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.35 m and an embankment defence level of 56.22 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 25.10 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.96 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.85 m and an embankment defence level of 54.97 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.10 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main

properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.50 m.

- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 1.67 m and an embankment defence level of 54.76 mAOD including a 0.6 m freeboard.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 1.64 m and a defence level of 54.46 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish the footbridge bridge on the Canal directly downstream of the railway bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.5 Option B2c - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Option B2c - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Description

This option aims to provide a SoP of 1% AP (100 year) through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B1a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 2.35 m with an embankment defence level of 55.22 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 19.10 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 0.96 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.00 m and an embankment defence level of 54.12 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 0.65 m.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 265 m. The wall has a maximum height of 1.79 m and a defence level of 54.61 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 145 m. The embankment has a maximum height of 2.78 m and an embankment defence level of 54.30 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 21.68 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.

- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.2 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish the footbridge bridge on the Canal directly downstream of the railway bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.6 Option B3a - Direct defences, flood gate, canal bridge removal

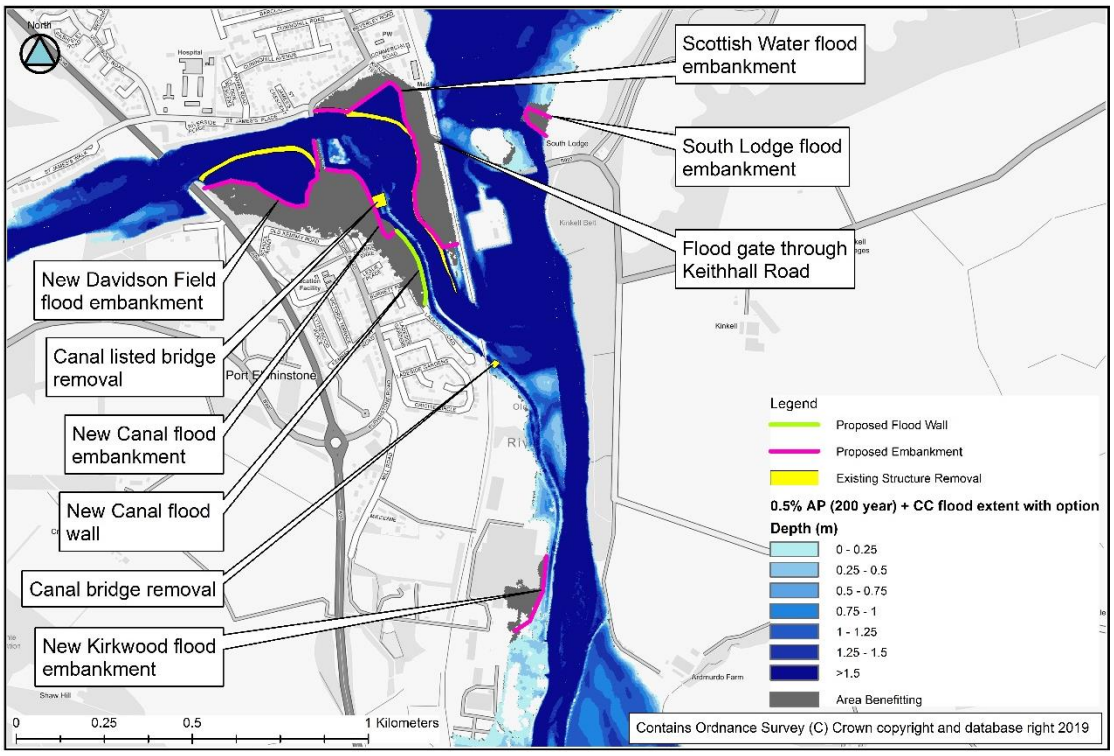
Option B3a - Direct defences, flood gate, canal bridge removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of direct defences, a flood gate and bridge removal. The works are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.91 m with an embankment defence level of 56.78 mAOD including a 0.6 m freeboard. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 2.52 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 3.21 m and an embankment defence level of 55.33 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.26 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.86 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.42 m and an embankment defence level of 55.51 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 19.52 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.39 m and a defence level of 55.21 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 3.28 m and an embankment defence level of 54.90 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.68 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Construct an embankment at the Canal outlet within Kirkwood Commercial Park for a length of 180 m. The embankment has a maximum height of 1.29 m and an embankment defence level of 53.60 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 12.74 m using a 5 m crest and 1 in 3 slopes, there is adequate space for this footprint. The embankment position has been chosen to protect the Old Mill structure as offset from the channel as possible where it extends to the point that the natural floodplain in Kirkwood remains in flood both to the North and South but no longer enter the building.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 2.3 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small

footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.



Standard of Protection (SOP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 597.79 m^3/s at Haughton gauging station on the River Don.

Alternative quick wins / Preliminary investigations

A review and testing of the existing embankments could be conducted to analyse whether they are suitable for an increase in height which would add engineering value to the amount of material wasted and used.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated. Due to lack of GI information a cut-off assumption of 0.5 m depth has been made, the cut-off depth will require further investigation at detailed design.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for Davidson embankment: Use of public and private roads, closure of car park may be required.
- Construction access for Scottish Water embankment: Use of public roads, road closure unlikely. Public footpath around the river may need to be closed.
- Construction access for canal embankment and flood wall: Use of public roads, road closure unlikely, likely closure of public footpath around canal.
- Construction access for South Lodge embankment: Use of public and private roads, road closure unlikely.
- Construction access for flood gates: Use of public roads, likely closure of Keithhall Road during construction.
- Construction access for canal modification: Use of public and private roads, road closure

unlikely though public footpath around canal likely to be closed.

- Construction access for Kirkwood embankment: Use of private roads, road closure unlikely.

Waste

- Expected quantity of waste material for embankment: 23,240 m^3
- Expected quantity of waste material from canal reprofile unknown.
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stock piles of soil and non-toxic spoil and construction waste should be located outside the functional floodplain (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath close to all direct defences.
- Houses: Canal direct defence in close proximity to properties.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- Consultation required with SNH and SEPA.
- Many Invasive Non Native Species (INNS) have been identified by NESBReC within the study area including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and Rhododendron. The field survey conducted by JBA primarily identified Giant Hogweed and Himalayan Balsam along the banks of the River Don. It is an offense to spread these INNS therefore control measures should be put in place during construction.
- Morphological and riparian improvement from embankment removal at Davidson Field and, upstream and downstream of the Scottish Water wastewater treatment works.

Health and safety hazards noted

Construction in close proximity to heavily used footpath.

Social and community issues

Some aesthetic issues as this option will require high embankments in a community space though embankments currently exist and are already accepted in this location. Some of the embankments are particularly high which may block views of the watercourses and lower amenity value in the area. The Davidson Field embankment primarily affects the properties at Riverside Park though a line of trees and bushes already exists here which currently restricts views, these should be retained to increase the amenity value of the defence. The Scottish Water embankment does not further constrict the view of any properties as the existing embankment already does so. The Canal direct defences will reduce visibility of the watercourses from the properties, further consultation and acceptance from the property owners may be required in order to prevent objections to the scheme.

Removal of canal bridges will remove a link from the canal bank to the island which is a known footpath therefore construction of a new bridge which does not interfere with the flood water has been incorporated into the scheme.

As well as the noted issues there is community benefit from redevelopment of the public access around the Canal. A redesign of the access will result in a safer development where there has been historical incidents of falling in to the canal.

Impact on other reaches

The works may interfere with the River Urie though as the two have been analysed together any detrimental impact has been accounted for.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works
- A ground investigation.
- Removing the flow path from Davidson Field into Port Elphinstone may add more pressure through the B993 Elphinstone Road bridge as this is the only flow path to downstream remaining. Reviewing the model, the option increases the water level by 0.37 m at the bridge. Due to such a large increase in water level it is recommended a scour assessment is carried out on the bridge at detailed design. Overland culverts may be required to reduce this risk. The water level under current conditions is already above bridge soffit and therefore a detailed scour assessment is advised.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR). In particular a complex CAR license will be likely for the Canal flood wall and CAR authorisation will be required for the demolition and reinstatement of the bridge.

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

Consider constructing embankments and walls so that they may be adapted in the future due to increased flows from climate change.

5.8.2.7 Option B3b - Direct defences, flood gate, canal bridge removal

Option B3b - Direct defences, flood gate, canal bridge removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of direct defences, a flood gate and bridge removal. All information other than the description are identical to option B3a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.32 m with an embankment defence level of 56.19 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.92 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.93 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.81 m and an embankment defence level of 54.93 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 21.86 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.46 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.02 m and an embankment defence level of 55.14 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17.12 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.09 m and a defence level of 54.54 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Construct an embankment at the Canal outlet within Kirkwood Commercial Park for a length of 90 m. The embankment has a maximum height of 1.09 m and an embankment defence

level of 53.40 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 11.54 m using a 5 m crest and 1 in 3 slopes, there is adequate space for this footprint.

- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.8 Option B4a - Direct defences on existing alignment, flood gate, canal bridge and weir removal

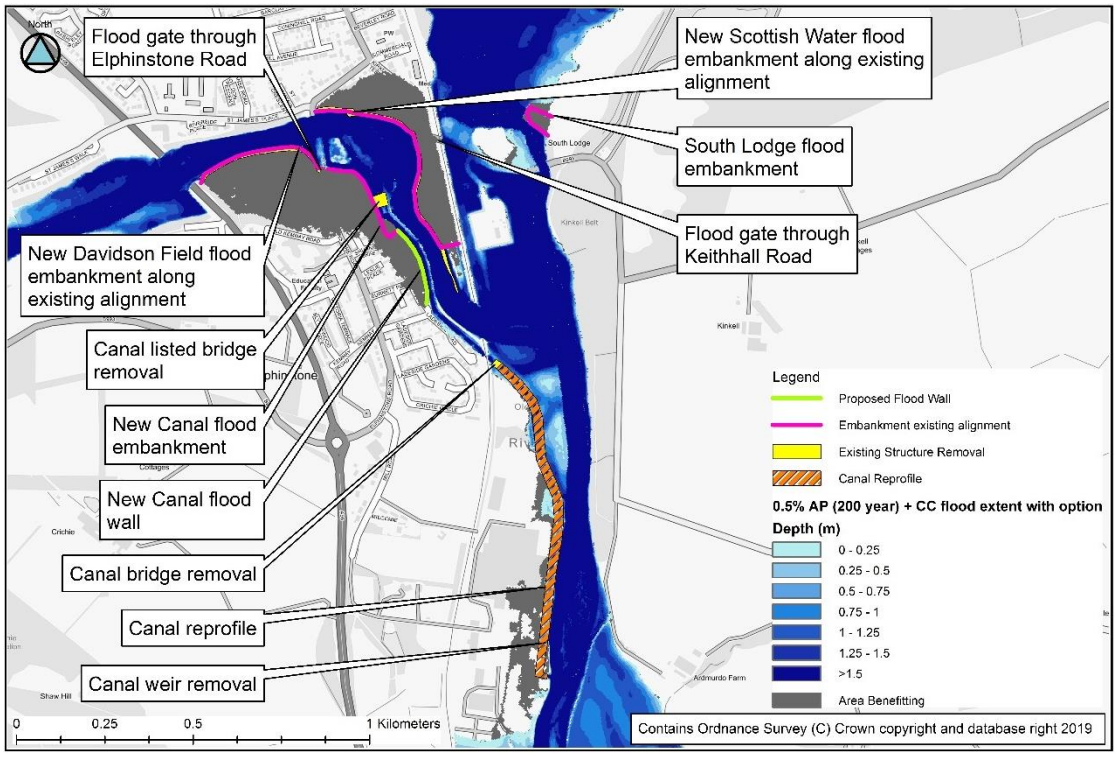
Option B1b - B4a - Direct defences on existing alignment, flood gate, canal bridge and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of direct defences, a flood gate and existing structure removal. The works are as follows:

- Construct an embankment along the existing alignment within Davidson Field for a length of 400 m with a maximum height of 3.41 m with an embankment defence level of 56.95 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 25.46 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 2.69 m.
- Construct an embankment along the original alignment on the left bank of the River Don at Keithhall Road for a length of 691 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.85 m and an embankment defence level of 55.71 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.10 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 2.24 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.53 m and an embankment defence level of 55.62 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 20.18 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.5 m and a defence level of 55.32 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 3.28 m and an embankment defence level of 54.90 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.68 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 2.3 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Install a flood gate approximately 12 m wide and 0.6 m high across Elphinstone Road at the Canal inlet to be manually operated with the flood warning scheme currently in place.

- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.



Standard of Protection (SOP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 597.79 m^3/s at Haughton gauging station on the River Don.

Alternative quick wins / Preliminary investigations

A review and testing of the material in the existing embankments could be conducted to analyse whether this material could be used for this option rather than discarded for the new embankment.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated. Due to lack of GI information a cut-off assumption of 0.5 m depth has been made, the cut-off depth will require further investigation at detailed design.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for Davidson embankment: Use of public and private roads, closure of car park may be required.
- Construction access for Scottish Water embankment: Use of public roads, road closure unlikely. Public footpath around the river may need to be closed.
- Construction access for canal embankment and flood wall: Use of public roads, road closure unlikely, likely closure of public footpath around canal.
- Construction access for South Lodge embankment: Use of public and private roads, road closure unlikely.

- Construction access for flood gates: Use of public roads, likely closure of Keithhall Road and Elphinstone Road during construction.
- Construction access for canal modification: Use of public and private roads, road closure unlikely though public footpath around canal likely to be closed.

Waste

- Expected quantity of waste material for embankment: 18,558 m^3
- Expected quantity of waste material from canal reprofile unknown.
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located outside the functional floodplain (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath close to all direct defences.
- Houses: Canal direct defence in close proximity to properties.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- Consultation required with SNH and SEPA.
- Many Invasive Non Native Species (INNS) have been identified by NESBReC within the study area including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and Rhododendron. The field survey conducted by JBA primarily identified Giant Hogweed and Himalayan Balsam along the banks of the River Don. It is an offense to spread these INNS therefore control measures should be put in place during construction.

Health and safety hazards noted

Construction in close proximity to heavily used footpath.

Social and community issues

Some aesthetic issues as this option will require high embankments in a community space though embankments currently exist and are already accepted in this location. The Canal direct defences will reduce visibility of the watercourses from the properties, further consultation and acceptance from the property owners may be required in order to prevent objections to the scheme.

Removal of canal bridges will remove a link from the canal bank to the island which is a known footpath therefore construction of a new bridge which does not interfere with the flood water has been incorporated into the scheme.

Consultation will be required with Kirkwood commercial park for modifications on the privately owned Canal.

As well as the noted issues there is community benefit from redevelopment of the public access around the Canal. A redesign of the access will result in a safer development where there has been historical incidents of falling in to the canal.

Impact on other reaches

The works may interfere with the River Urie though as the two have been analysed together any detrimental impact has been accounted for.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.

- A ground investigation.
- Removing the flow path from Davidson Field into Port Elphinstone may add more pressure through the B993 Elphinstone Road bridge as this is the only flow path to downstream remaining. Reviewing the model, the option increases the water level by 0.37 m at the bridge. Due to such a large increase in water level it is recommended a scour assessment is carried out on the bridge at detailed design. Overland culverts may be required to reduce this risk. The water level under current conditions is already above bridge soffit and therefore a detailed scour assessment is advised.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR). In particular a complex CAR license will be likely for the Canal flood wall and CAR authorisation will be required for the demolition and reinstatement of the bridge.

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

Consider constructing embankments and walls so that they may be adapted in the future due to increased flows from climate change.

5.8.2.9 Option B4b - Direct defences on existing alignment, flood gate, canal bridge and weir removal

Option B3b - Direct defences, flood gate, canal bridge removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B4a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 400 m with a maximum height of 3.07 m with an embankment defence level of 56.11 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 23.42 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.85 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 691 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.40 m and an embankment defence level of 55.26 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 19.40 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.79 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.11 m and an embankment defence level of 55.20 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17.66 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.08 m and a defence level of 54.90 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.

- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream and 950 m upstream to a more gradual gradient.
- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.10 Option B5 - Direct defences, flood gate, canal bridge and weir removal

Option B5 - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) in area B and 0.1% AP (1000 year) to the Old Mill at Kirkwood through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B3a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.32 m with an embankment defence level of 56.19 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.92 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.93 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.81 m and an embankment defence level of 54.93 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 21.86 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.46 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.02 m and an embankment defence level of 55.14 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17.12 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.39 m and a defence level of 54.84 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Construct an embankment at the Canal outlet within Kirkwood Commercial Park for a length of 240 m. The embankment has a maximum height of 2.63 m and an embankment defence level of 55.39 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 20.78 m using a 5 m crest and 1 in 3 slopes, from initial investigation there is enough space for this embankment though slopes or crest width may need to be re-evaluated at detailed design. The embankment position has been chosen to protect the Old Mill structure as offset from the channel as possible where it extends to the point that the natural floodplain in Kirkwood remains in flood both to the North and South but no longer enter the building.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the footbridge bridge on the Canal directly downstream of the railway bridge. The

small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

5.8.2.11 Option B6 - Direct defences on existing alignment, flood gate, canal bridge and weir removal

Option B6 - Direct defences on existing alignment, flood gate, canal bridge and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) in area B and 0.1% AP (1000 year) at Kirkwood through construction of direct defences, a flood gate and existing structure removal. The works are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 400 m with a maximum height of 3.07 m with an embankment defence level of 56.11 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 23.42 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 1.85 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 691 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 2.40 m and an embankment defence level of 55.26 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 19.40 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.79 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.11 m and an embankment defence level of 55.20 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 17.66 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.08 m and a defence level of 54.90 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 2.98 m and an embankment defence level of 54.50 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 22.88 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Construct an embankment at the Canal outlet within Kirkwood Commercial Park for a length of 240 m. The embankment has a maximum height of 2.63 m and an embankment defence level of 55.39 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 20.78 m using a 5 m crest and 1 in 3 slopes, from initial investigation there is enough space for this embankment though slopes or crest width may need to be re-evaluated at detailed design. The embankment position has been chosen to protect the Old Mill structure as offset from the channel as possible where it extends to the point that the natural floodplain in Kirkwood remains in flood both to the North and South but no longer enter the building.
- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 1.8 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Install a flood gate approximately 12 m wide and 0.6 m high across Elphinstone Road at the Canal inlet to be manually operated with the flood warning scheme currently in place.
- Demolish the weir at the Canal outlet and reprofile the canal a further 10 m downstream

and 950 m upstream to a more gradual gradient.

- Demolish 2 no. bridges on the Canal including the listed bridge near the inlet and the small footbridge after the rail bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

Standard of Protection (SOP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 598 m^3/s at Haughton gauging station on the River Don.

Alternative quick wins / Preliminary investigations

A review and testing of the material in the existing embankments could be conducted to analyse whether this material could be used for this option rather than discarded for the new embankment.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated, the cut-off depth will require further investigation at detailed design.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for Davidson embankment: Use of public and private roads, closure of car park may be required.
- Construction access for Scottish Water embankment: Use of public roads, road closure unlikely. Public footpath around the river may need to be closed.
- Construction access for canal embankment and flood wall: Use of public roads, road closure unlikely, likely closure of public footpath around canal.
- Construction access for South Lodge embankment: Use of public and private roads, road closure unlikely.
- Construction access for flood gates: Use of public roads, likely closure of Keithhall Road and Elphinstone Road during construction.
- Construction access for canal modification: Use of public and private roads, road closure unlikely though public footpath around canal likely to be closed.

Waste

- Expected quantity of waste material for embankment: 18,558 m^3
- Expected quantity of waste material from canal reprofile unknown.
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located outside the functional floodplain (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath close to all direct defences.
- Houses: Canal direct defence in close proximity to properties.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and

hydromorphology.

- Consultation required with SNH and SEPA.
- Many Invasive Non Native Species (INNS) have been identified by NESBReC within the study area including Giant Hogweed, Himalayan Balsam, Himalayan Cotoneaster, Montbretia, Japanese Knotweed, Yellow Archangel and Rhododendron. The field survey conducted by JBA primarily identified Giant Hogweed and Himalayan Balsam along the banks of the River Don. It is an offense to spread these INNS therefore control measures should be put in place during construction.

Health and safety hazards noted

Construction in close proximity to heavily used footpath.

Social and community issues

Some aesthetic issues as this option will require high embankments in a community space though embankments currently exist and are already accepted in this location. Some of the embankments are particularly high which may block views of the watercourses and lower amenity value in the area. The Davidson Field embankment primarily affects the properties at Riverside Park though a line of trees and bushes already exists here which currently restricts views, these should be retained to increase the amenity value of the defence. The Scottish Water embankment does not further constrict the view of any properties as the existing embankment already does so. The Canal direct defences will reduce visibility of the watercourses from the properties, further consultation and acceptance from the property owners may be required in order to prevent objections to the scheme.

Removal of canal bridges will remove a link from the canal bank to the island which is a known footpath therefore construction of a new bridge which does not interfere with the flood water has been incorporated into the scheme.

Consultation will be required with Kirkwood commercial park for modifications on the privately owned Canal.

As well as the noted issues there is community benefit from redevelopment of the public access around the Canal. A redesign of the access will result in a safer development where there has been historical incidents of falling in to the canal.

Impact on other reaches

The works may interfere with the River Urie though as the two have been analysed together any detrimental impact has been accounted for.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- Removing the flow path from Davidson Field into Port Elphinstone may add more pressure through the B993 Elphinstone Road bridge as this is the only flow path to downstream remaining. Reviewing the model, the option increases the water level by 0.37 m at the bridge. Due to such a large increase in water level it is recommended a scour assessment is carried out on the bridge at detailed design. Overland culverts may be required to reduce this risk. The water level under current conditions is already above bridge soffit and therefore a detailed scour assessment is advised.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR). In particular a complex CAR license will be likely for the Canal flood wall and CAR authorisation will be required for the demolition and reinstatement of the bridge.

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

Consider constructing embankments and walls so that they may be adapted in the future due to increased flows from climate change.

5.9 Initial comparison of options for area B

An initial analysis of the damages against the costs to implement alleviation measures along with residual risk has indicated the high likelihood of resulting low benefit cost ratios. At this stage it is therefore important to identity the most achievable sustainable option and hence the best option in

each area for each standard of protection to take forward into the economic appraisal in Section 5.10.

For Area A there is only one option considered whereas for Area B a comparison has been made to find the best option to be taken forward for each standard of protection shown in Table 5-5 below.

Table 5-5: Area B comparison

Area B Variation	0.5% (200 year)	0.5% (200 year) + climate change	Cost (£k)
Variation 1	**B1b** - Solution involves hard engineering with set back embankments which has environmental benefit. Costs are generally high, particularly due to the length of embankments required but also the higher wall heights on the Canal where walls are substantially more expensive than embankments.	**B1a** - Solution with inclusion of climate change results in higher costs from larger direct defences.	200 year: 9,815 200 year + CC: 13,017
Variation 2 (listed bridge retained)	B2b - Solution involves hard engineering with set back embankments though retaining the listed bridge on the Canal. This option has environmental benefit. Costs are slightly higher for this option as embankment heights are increased on the Canal and Scottish Water embankments.	B2a - Solution with inclusion of climate change results in higher costs from larger direct defences. Costs are the lowest for the 200CC event due to the inclusion of the Canal listed bridge holding back water upstream of the proposed flood wall. This has resulted in the full length of the wall being at a lower height and hence a lot more cost effective per unit metre.	200 year: 9,984 200 year + CC: 11,836
Variation 3 (weir retained)	B3b - Solution involves hard engineering with set back embankments while retaining the weir at the Canal outlet but incorporating an embankment in this area instead. This option has environmental benefit. This option only marginally differs in cost from option 1 showing that both weir removal or an embankment at the Canal outlet is a viable solution.	B3a - Solution with inclusion of climate change results in higher costs from larger direct defences.	200 year: 10,004 200 year + CC: 13,050
Variation 4 (existing alignment)	B4b - Solution involves hard engineering using the existing embankment alignment for the Davidson and Scottish Water embankments. This option is the most cost effective for this return period due to the reduction in length of the embankments. Though it is more cost effective it does not have the same value such as the RBMP benefits of formalising more of the floodplain.	B4a - Solution with inclusion of climate change results in higher costs from larger direct defences. This option is more cost effective than option 1 and 3 due to the reduction in length of the embankments. Though it is more cost effective it does not have the same value such as the RBMP benefits of formalising more of the floodplain.	200 year: 9,512 200 year + CC: 12,751

Comparing the options above the following has been taken forward for each event:

- 0.5% AP (200 year) + CC - Variation 2 has been taken forward as it is the most cost effective option while also giving additional environmental benefit through offset embankments.
- 0.5% AP (200 year) - Variation 2 has been taken forward due to all options producing a similar cost it gives environmental benefit of offsetting the embankments while also giving an easier solution by retaining all listed structures.

5.10 Flood mitigation options

The following section details the flood mitigation options for the full study area taking different combinations of options from the previous sections in each design area, these will ultimately be used as the decision for the preferred option in Inverurie and Port Elphinstone.

*Increasing Kirkwood to a SoP of 0.1% AP (1000 year) has been considered in order to reduce residual damages to improve the sustainability of the flood scheme. This is discussed further in section 8.3.

5.10.1 Option 1 - Direct defences, flood gate, Canal footbridge downstream of rail bridge removal (listed bridge retained) and weir removal - SoP 0.5% AP (200 year) plus climate change

Option 1 is a combination of the following options discussed in Section 5.8:

- **Area A - Option A1a:** Direct defence upstream of Oldmeldrum Road.
- **Area B - Option B2a:** Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 1.1 (1 of 4) AIZ-JBAU-IK-00-DR-HM-0001-Option1_Key_Plan-A1-C01.pdf
- Figure 1.2 (2 of 4) AIZ-JBAU-IK-00-DR-HM-0002-Option1_Area_A-A1-C01.pdf
- Figure 1.3 (3 of 4) AIZ-JBAU-IK-00-DR-HM-0003-Option1_Area_Bi-A1-C01.pdf
- Figure 1.4 (4 of 4) AIZ-JBAU-IK-00-DR-HM-0004-Option1_Area_Bii-A1-C01.pdf

5.10.2 Option 2 - Direct defences, flood gate, Canal footbridge downstream of rail bridge removal (listed bridge retained) and weir removal - SoP 0.5% AP (200 year)

Option 2 is a combination of the following options discussed in Section 5.8, this differs from option 1 as it reduces the SoP to 0.5% AP (200 year):

- **Area A - Option A1b:** Direct defence upstream of Oldmeldrum Road.
- **Area B - Option B2b:** Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 2.1 (1 of 4) AIZ-JBAU-IK-00-DR-HM-0005-Option2_Key_Plan-A1-C01.pdf
- Figure 2.2 (2 of 4) AIZ-JBAU-IK-00-DR-HM-0006-Option2_Area_A-A1-C01.pdf
- Figure 2.3 (3 of 4) AIZ-JBAU-IK-00-DR-HM-0007-Option2_Area_Bi-A1-C01.pdf
- Figure 2.4 (4 of 4) AIZ-JBAU-IK-00-DR-HM-0008-Option2_Area_Bii-A1-C01.pdf

5.10.3 Option 3 - Direct defences, flood gate, Canal footbridge downstream of rail bridge removal (listed bridge retained) and weir removal - SoP 0.5% AP (200 year) for area B

Option 3 is a combination of the following options discussed in Section 5.8, this option differs from option 2 as area A is now undefended due to only 2 properties at risk during the 0.5% AP (200 year) event:

- **Area A -** Undefended.
- **Area B - Option B2b:** Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 3.1 (1 of 3) AIZ-JBAU-IK-00-DR-HM-0009-Option3_Key_Plan-A1-C01.pdf
- Figure 3.2 (2 of 3) AIZ-JBAU-IK-00-DR-HM-0011-Option3_Area_Bi-A1-C01.pdf
- Figure 3.3 (3 of 3) AIZ-JBAU-IK-00-DR-HM-0012-Option3_Area_Bii-A1-C01.pdf

5.10.4 Option 4 - Direct defences on existing alignment, flood gate, Canal footbridge downstream of rail bridge removal (listed bridge retained) and weir removal - SoP 0.5% AP (100 year) for area B

Option 4 is a combination of the following options discussed in Section 5.8, this option differs from option 3 as it reduces the SoP in area B to 1% AP (100 year):

- **Area A -** Undefended.
- **Area B - Option B2c:** Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 4.1 (1 of 3) AIZ-JBAU-IK-00-DR-HM-0013-Option4_Key_Plan-A1-C01.pdf
- Figure 4.2 (2 of 3) AIZ-JBAU-IK-00-DR-HM-0015-Option4_Area_Bi-A1-C01.pdf
- Figure 4.3 (3 of 3) AIZ-JBAU-IK-00-DR-HM-0016-Option4_Area_Bii-A1-C01.pdf

5.11 Option 5

Option 5 has been considered to lower the residual risk and hence increase the benefit by protecting the Old Mill building at Kirkwood against the 0.1% AP (1000 year) event, discussed further in Section 8.3. As mentioned, this involves preventing the Old Mill building from flooding which is no longer in operation and is now to be redeveloped. Due to the large size of this structure, high damages are incurred during low probability events. Protection to the 0.1% AP (1000 year) dramatically reduces these damages and the residual risk. It is important to note that these measures are not established to facilitate development of an area which under SPP lies partially within the functional floodplain. It is understood the development of the commercial park is ongoing, and any future development would need to consider the existing flood risk with respect to requirements for land raising, compensatory storage, finished floor levels and, access and egress. In addition, under Option 5 there are areas of the commercial park which remain at flood risk, and hence development within these areas should be avoided.

5.11.1 Option 5 - Direct defences including Kirkwood to SoP 0.1 % AP (1000 year), flood gate and Canal footbridge downstream of rail bridge removal (listed bridge retained)

Option 5 is a combination of the following options discussed in Section 5.8, this option differs from option 4 as it retains the weir and instead places and embankment at Kirkwood to defend it to the 0.1% AP (1000 year) event:

- **Area A - Option A1b:** Direct defence upstream of Oldmeldrum Road.
- **Area B - Option B5:** Direct defences, flood gate and canal bridge removal (listed bridge retained)

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 5.1 (1 of 4) AIZ-JBAU-IK-00-DR-HM-0017-Option5_Key_Plan-A1-C01.pdf
- Figure 5.2 (2 of 4) AIZ-JBAU-IK-00-DR-HM-0018-Option5_Area_A-A1-C01.pdf
- Figure 5.3 (3 of 4) AIZ-JBAU-IK-00-DR-HM-0019-Option5_Area_Bi-A1-C01.pdf
- Figure 5.4 (4 of 4) AIZ-JBAU-IK-00-DR-HM-0020-Option5_Area_Bii-A1-C01.pdf

5.12 Option 6

Option 6 has been considered to improve costs and floodplain connectivity as a future option if during the full 100 year appraisal period the western waste water treatment works is abandoned by Scottish Water. This would provide the potential for a more robust solution and therefore has been investigated as an alternate future option. The option is described in more detail in the following section.

5.12.1 Option 6 - Direct defences including Kirkwood to SoP 0.1 % AP (1000 year), flood gate and Canal footbridge downstream of rail bridge removal (listed bridge retained) SW WWTW undefended

Option 6 is a combination of the following options discussed in Section 5.8, this option differs from option 4 as the Scottish Water embankment is trimmed so that the older part of the wastewater treatment works (to the west of the railway line) is unprotected on the floodplain, based on the assumption that long term it will be demolished. This option also assumes that the soil from the original embankments can be reused:

- **Area A - Option A1b:** Direct defence upstream of Oldmeldrum Road.
- **Area B - Option B6:** Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- Figure 6.1 (1 of 4)AIZ-JBAU-IK-00-DR-HM-0021-Option6_Key_Plan-A1-C01.pdf
- Figure 6.2 (2 of 4)AIZ-JBAU-IK-00-DR-HM-0022-Option6_Area_A-A1-C01.pdf
- Figure 6.3 (3 of 4)AIZ-JBAU-IK-00-DR-HM-0023-Option6_Area_Bi-A1-C01.pdf
- Figure 6.4 (4 of 4)AIZ-JBAU-IK-00-DR-HM-0024-Option6_Area_Bii-A1-C01.pdf

6 Investment appraisal

6.1 Damage methodology

Flood damage assessment can include direct, indirect, tangible and intangible aspects of flooding, as shown in Figure 6-1. Direct damages are the most significant in monetary terms, although the FHRC Multi Coloured Manual (MCM)[13] and additional research provide additional methodologies, recommendations and estimates to account for the indirect and intangible aspects of flood damage.

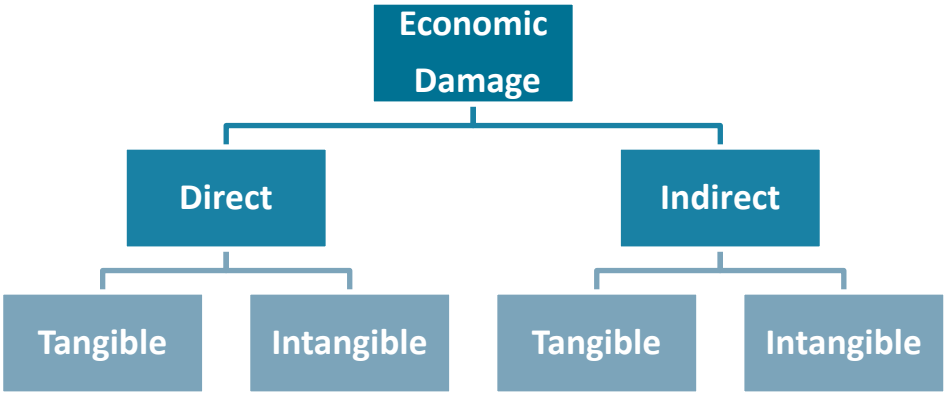


Figure 6-1: Aspects of flood damage

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 and additional data used to calculate the flood damages is provided in Appendix A.

6.2 Baseline damages

Baseline damage results are presented for the Do Nothing and Do Minimum options below.

Do Nothing

Assumptions:

Maintenance ceased, increasing hydraulic roughness due to vegetation growth and degradation of banks.

Bridges are blocked using a risk-based approach either by widening their piers by 0.5 m, widening their abutments by 0.2 m or dropping the soffits by 0.2 m.

Properties at risk:

The total number of properties inundated above threshold level for the Do Nothing scenario both with and without climate change within Inverurie and Port Elphinstone has been assessed and is provided in the table below:

Return period (years)	2	5	10	30	50	75	100	200	1000
Residential	0	0	2	7	25	59	81	92	147
Non-residential	0	0	4	5	24	27	27	30	39
Total	0	0	6	12	49	86	108	122	186

13 Handbook for economic appraisal, MCM, Flood and coastal erosion risk management, 2017

Return period (years)	2CC	5CC	10 CC	30 CC	50 CC	75 CC	100 CC	200 CC	1000CC
Residential	0	2	6	30	83	88	95	105	186
Non-residential	0	4	5	27	27	29	31	32	56
Total	0	6	11	57	110	117	126	137	242

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 ten properties, PVd values without climate change, are listed in the table below.

Rank	Property address	PVd (£k)	Percentage of total PVd
1	OLD MILL, KIRKWOOD AB51 5NR	4081.36	44.8
2	KEITH-HALL ROAD, AB51 3UA	916.09	10.1
3	KEITH-HALL ROAD, AB51 3UA	412.26	4.5
4	KEITH-HALL ROAD, AB51 3UA	364.44	4.0
5	[redacted] RIVERSIDE PARK AB51 3SB	181.40	2.0
6	CANAL VIEW AB51 3UE	170.02	1.9
7	KEITH-HALL ROAD, AB51 3UA	158.97	1.7
8	[redacted] RIVERSIDE PARK AB51 3SB	157.08	1.7
9	[redacted] KEITHHALL ROAD AB51 3UA	138.51	1.5
10	SCOTTISH WATER WASTEWATER TREATMENT WORKS	138.09	1.5

Event property damages (at year 0):

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix B. 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	30	50	75	100	200	1000
Residential	0	0	0	0	1,497	2,973	3,443	4,369	8,447
Non-residential	0	0	0	0	2,296	2,917	3,166	8,253	49,107
Total	0	0	0	0	3,793	5,889	6,609	12,622	57,554

Return period (years)	2 CC	5 CC	10 CC	30 CC	50 CC	75 CC	100 CC	200 CC	1000 CC
Residential	0	0	0	2,399	3,495	3,995	4,422	5,599	10,770
Non-residential	0	0	0	2,713	3,233	3,578	9,531	25,834	61,891
Total	0	0	0	5,112	6,728	7,573	13,954	31,433	72,661

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.

The AAD for the year 0 without breach was calculated as 283.8 (£k).

The AAD for the year 0 without breach but with the inclusion of climate change was calculated as 604.7 (£k).

Event property damages (at year 20, embankments breached):

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix B. 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	30	50	75	100	200	1000
Residential	0	0	47	316	920	2,094	3,093	4,226	7,827
Non-residential	0	0	841	1,780	2,210	3,071	3,280	8,164	48,476
Total	0	0	888	2,096	3,130	5,166	6,373	12,389	56,303

Return period (years)	2 CC	5 CC	10 CC	30 CC	50 CC	75 CC	100 CC	200 CC	1000 CC
Residential	0	32	159	1,312	3,197	3,855	4,289	5,433	10,936
Non-residential	0	837	1,490	2,879	3,338	3,647	9,440	25,643	61,300
Total	0	869	1,649	4,191	6,535	7,502	13,729	31,076	72,237

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.

The AAD for the year 20 breach was calculated as 305.29 (£k).

The AAD for the year 20 breach with the inclusion of climate change was calculated as 568.1 (£k)

Indirect and intangible damages:

A summary of the proportion of total damages by each damage component is provided in the table below. These were converted to AAD and were taken forward to the full 100 appraisal period, the values were then changed at year 20 to give a total PVd at the end. As discussed in Section 4.5 the climate change values are also provided as the AAD is interpolated up to the higher value with climate change at year 2080.

Do Nothing flood damages (£k):

Year	Property PVd	Capped Property PVd	Indirect PVd	Intangible PVd	Total Capped PVd
0	9,224	8,461	457	575	8,918
0 + CC	21,834	18,028	974	766	19,002
20	13,477	9,102	492	499	9,593
20 + CC	29,830	16,938	915	730	17,852

Do Minimum

Assumptions:

Maintenance continued in the channel and on the banks. No bridge blockage assumed.

Properties at risk:

The total number of properties inundated above threshold level for the Do Minimum scenario both with and without climate change within Inverurie and Port Elphinstone has been assessed and is provided in the table below:

Return period (years)	2	5	10	30	50	75	100	200	1000
Residential	0	0	0	0	1	57	79	88	140
Non-residential	0	0	0	0	5	27	27	28	35
Total	0	0	0	0	6	84	106	116	175

Return period (years)	2CC	5CC	10 CC	30 CC	50 CC	75 CC	100CC	200CC	1000CC
Residential	0	0	0	25	81	85	88	106	175
Non-residential	0	0	0	22	27	27	29	32	46
Total	0	0	0	47	108	112	117	138	221

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 ten properties are listed in the table below.

Rank	Property address	PVd (£k)	Percentage of total PVd
1	OLD MILL, KIRKWOOD AB51 5NR	2912.89	46.0
2	KEITH-HALL ROAD, AB51 3UA	916.09	14.5
3	CANAL VIEW AB51 3UE	170.02	2.7
4	KEITH-HALL ROAD, AB51 3UA	113.28	1.8
5	SCOTTISH WATER WASTEWATER TREATMENT WORKS	100.89	1.6
6	KEITH-HALL ROAD, AB51 3UA	96.80	1.5
7	CANAL VIEW AB51 3UE	75.80	1.2
8	[redacted] RIVERSIDE PARK AB51 3SB	61.36	1.0
9	[redacted] RIVERSIDE PARK AB51 3SB	57.70	0.9
10	[redacted]RIVERSIDE PARK AB51 3SB	52.69	0.8

Event property damages:

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix B. 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	30	50	75	100	200	200CC	1000

Residential	0	0	0	0	5	1,890	2,920	4,023	5,276	7,664
Non-residential	0	0	0	0	776	2,577	2,914	4,730	21,223	38,283
Total	0	0	0	0	781	4,467	5,835	8,753	26,499	45,948

Return period (years)	2 CC	5 CC	10 CC	30 CC	50 CC	75 CC	100 CC	200 CC	1000 CC
Residential	0	0	0	1,042	2,998	3,621	3,996	5,276	10,835
Non-residential	0	0	0	2,168	2,981	3,326	5,739	21,223	62,847
Total	0	0	0	3,210	5,979	6,948	9,735	26,499	73,681

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.

Indirect and intangible damages:

A summary of the proportion of total damages by each damage component is provided in the table below.

Do Nothing flood damages (£k):

Scenario	Property PVd	Capped Property PVd	Indirect PVd	Intangible PVd	Total Capped PVd
Without CC	6,667	6,330	342	415	6,672
With CC	17,297	14,034	758	700	14,792

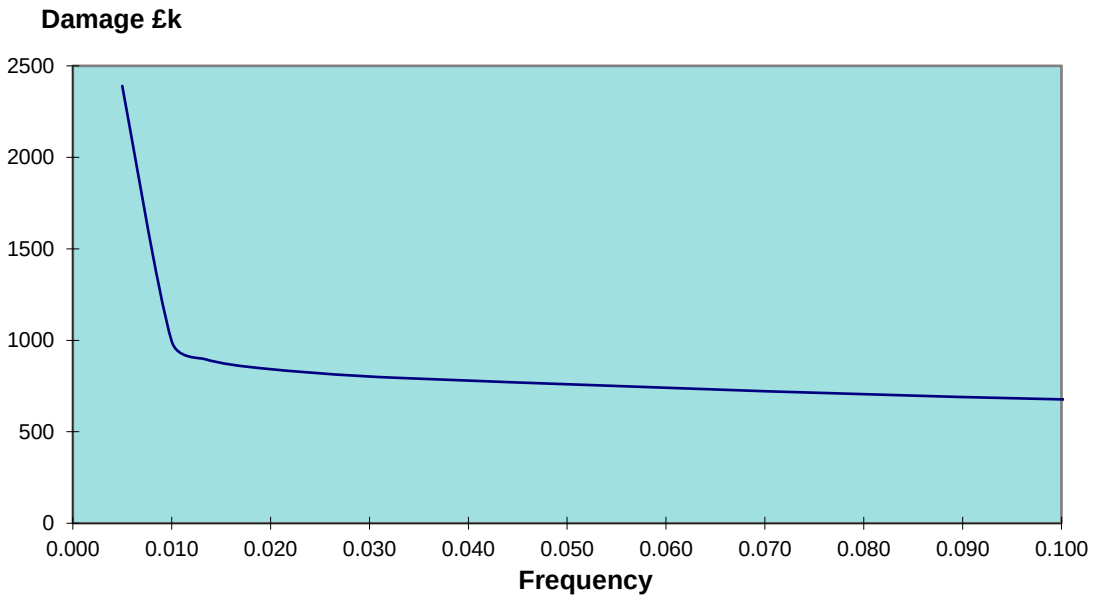


Figure 6-2: Do-Nothing damage curve

Figure 6-2 shows how damages increase during the higher events for the Do Nothing scenario against the probability of that event occurring, in order to obtain a Present value Damage (PVd) the probability of the event occurring over the 100 year appraisal period is considered. Analysis of the frequency that damages are expected to occur shows that the lower return periods have a dominant impact on flood damages, as is often the case. However, events above the 1% AP (100 year) event also make a large contribution to the overall damages, meaning that within Inverurie there would be great benefit in protecting against the largest magnitude flood events.

6.3 Options

The flood damages for each option were calculated for each return period up to the 0.1% AP (1000 year) 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 damages avoided as a result of the options' interventions, also known as the benefit.

6.4 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 £2.9 m - £12.1 m, leaving comparative residual present value damages in the range £1.2 m - £10.6 m. The Do Minimum option reduces the Do Nothing damages by roughly 21 % and the defended options reduce this further by varying degrees.

Table 6-1: Damage benefit summary

	DN	DM	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Option name	Do Nothing	Do Minimum	Hard engineering to high SoP plus climate change	Hard engineering to high SoP	Hard engineering, area A undefended	Hard engineering, area A undefended and lowered SoP	Hard engineering, area A undefended and Kirkwood defended to the 1000 year	Hard engineering, area A undefended and SW WWTW unprotected
Standard of Protection	50% AP (2 year)	10% AP (10 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	Area A - 3.33% AP (30 year) Area B - 0.5% AP (200 year)	Area A - 3.33% AP (30 year) Area B - 1% AP (100 year)	Area A - 3.33% AP (30 year) Area B - 0.5% AP (200 year)	Area A - 3.33% AP (30 year) Area B - 0.5% AP (200 year)
BENEFITS:								
PV monetised flood damages (£k)	13,421	10,557	2,465	4,062	4,103	4,103	1,309	1,234
Total PV damages avoided/ benefits (£k)	-		10,956	9,359	9,318	9,318	12,112	12,188

7 Cost estimates

7.1 Price Base Date

The price base date is January 2019. The costs and benefits have been discounted over the 100 year life of the scheme to determine present values.

7.2 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.

The Environment Agency's 'Long Term Costing' tool (2012) was the basis of all costs for this assessment to provide a uniform approach to costing across the flood studies.

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.

7.3 Embankment costing assumption

The cost per m^3 for embankments with a volume greater than 15,000 m^3 is £42. The total volume of the embankments for all options is substantial with some options producing single embankments around 30,000 m^3. As the embankments are in close proximity to each other and it is likely that some element of bulk buying will be used in the construction phase £42 per m^3 has been used as the unit cost for all embankments rather than solely the ones over the 15,000 m^3 threshold.

7.4 Maintenance costs

The Environment Agency Long Term Costing tool was used to calculate maintenance costs. 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[14]. 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.

7.4.1 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.

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This uplift is applied to present value capital and present value maintenance costs after their calculation.

7.5 Option 1 - Hard engineering to high SoP plus climate change

This option consists of the following:

- Area A
  - Flood embankment along Oldmeldrum Road, 385 m long, max height 3.76 m, total volume 14,888 m^3
  - Flood embankment around properties at "Gaulds Gas", 101 m long, max height 1.43 m, total volume 1,237 m^3
- Area B
  - Flood embankment offset in Davidson Field, 507 m long, max height 3.94 m, total volume 30,408 m^3
  - Flood embankment offset along Keithhall road and the SW WWTW, 803 m long, max height 3.24 m, total 28,655 m^3
  - Flood embankment along the right bank of the Canal, 319 m long, max height 2.08 m, total volume 5,428 m^3
  - Concrete flood wall along the right bank of the Canal, 232 m long, average height 1.7 m, assumed piled foundations
  - Flood embankment around the properties at South Lodge, 170 m long, max height 3.28 m, total volume 4,833 m^3
  - Remove 5,505m^3 of existing embankment soil at Davidson Field and SW WWTW
  - Install a flood gate at Keithhall road approximately 12 m wide and 2.3 m high
  - Demolish weir at the Canal outlet and reprofile 961 m of Canal to a more gradual gradient
  - Demolish 26.5 m^2 of existing Canal bridge
  - Construction of 26.5 m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) plus climate change standard of protection and on near immediate initiation of works.

Table 7-1: Option 1 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.76 m	14,888 m^3	£42	£625,296
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	3.94 m	30,408 m^3	£42	£1,277,221
Keithhall road embankment	3.24 m	28,655 m^3	£42	£1,203,590
Canal embankment	2.08 m	5,428 m^3	£42	£227,976
Canal flood wall	1.7 m	232 m	£5,473	£1,269,758
South Lodge embankment	3.28 m	4,833 m^3	£42	£202,986
Existing embankment excavation	-	5,505 m^3	£81	£448,437
Keithhall Road flood gate	-	12 m x 2.3 m	£169,000	£169,000
Canal reprofile	-	961 m	£562	£540,453
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£6,066,730

Table 7-2: Option 1 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	607	607
Capital cost	6,067	6,067
Maintenance cost	2,489	724
Total	**9,163**	**7,398**
Total incl. Optimism Bias	-	11,837

7.6 Option 2 - Hard engineering to high SoP

This option consists of the following:

Area A

- Flood embankment along Oldmeldrum Road, 385 m long, max height 3.38 m, total volume 11,845 m^3
- Flood embankment around properties at "Gaulds Gas", 101 m long, max height 1.43 m, total volume 1,237 m^3

Area B

- Flood embankment offset in Davidson Field, 507 m long, max height 3.35 m, total volume 22,741 m^3
- Flood embankment offset along Keithhall road and the SW WWTW, 803 m long, max height 2.85 m, total 21,398 m^3
- Flood embankment along the right bank of the Canal, 319 m long, max height 1.67 m, total volume 3,541 m^3
- Concrete flood wall along the right bank of the Canal, 207 m long, average height 1.3 m, assumed piled foundations
- Lowered Canal flood wall for final 25 m length, average height 0.9 m, assumed piled foundations
- Flood embankment around the properties at South Lodge, 170 m long, max height 2.98 m, total volume 3,900 m^3
- Remove 5,505m^3 of existing embankment soil at Davidson Field and SW WWTW
- Install a flood gate at Keithhall road approximately 12 m wide and 1.8 m high
- Demolish weir at the Canal outlet and reprofile 961 m of Canal to a more gradual gradient
- Demolish 26.5 m^2 of existing Canal bridge
- Construction of 26.5m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-3: Option 2 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.38 m	11,845 m^3	£42	£497,490
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	3.35 m	22,741 m^3	£42	£955,186
Keithhall road embankment	3.24 m	21,398 m^3	£42	£898,776
Canal embankment	1.67 m	3,541 m^3	£42	£148,722
Canal flood wall	1.3 m	207 m	£5,473	£1,132,930
Lowered Canal flood wall	0.9 m	25 m	2,431	£60,777
South Lodge embankment	2.98 m	3,900 m^3	£42	£163,800
Existing embankment excavation	-	5,505 m^3	£81	£448,437

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Keithhall Road flood gate	-	12 m x 1.8 m	£71,000	£71,000
Canal reprofile	-	961 m	£562	£540,453
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£5,019,584

Table 7-4: Option 2 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	502	502
Capital cost	5,020	5,020
Maintenance cost	2,468	718
Total	**7,990**	**6,240**
Total incl. Optimism Bias	-	9,984

7.7 Option 3 - Hard engineering, area A undefended

This option consists of the following:

Area B

- Flood embankment offset in Davidson Field, 507 m long, max height 3.35 m, total volume 22,741 m^3
- Flood embankment offset along Keithhall road and the SW WWTW, 803 m long, max height 2.85 m, total 21,398 m^3
- Flood embankment along the right bank of the Canal, 319 m long, max height 1.67 m, total volume 3,541 m^3
- Concrete flood wall along the right bank of the Canal, 207 m long, average height 1.3 m, assumed piled foundations
- Lowered Canal flood wall for final 25 m length, average height 0.9 m, assumed piled foundations
- Flood embankment around the properties at South Lodge, 170 m long, max height 2.98 m, total volume 3,900 m^3
- Remove 5,505m^3 of existing embankment soil at Davidson Field and SW WWTW
- Install a flood gate at Keithhall road approximately 12 m wide and 1.8 m high
- Demolish weir at the Canal outlet and reprofile 961 m of Canal to a more gradual gradient
- Demolish 26.5 m^2 of existing Canal bridge
- Construction of 26.5 m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) standard of protection in Area B and on near immediate initiation of works.

Table 7-5: Option 3 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Davidson Field embankment	3.35 m	22,741 m^3	£42	£955,186
Keithhall road embankment	3.24 m	21,398 m^3	£42	£898,776
Canal embankment	1.67 m	3,541 m^3	£42	£148,722
Canal flood wall	1.3 m	207 m	£5,473	£1,132,930

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Lowered Canal flood wall	0.9 m	25 m	2,431	£60,777
South Lodge embankment	2.98 m	3,900 m^3	£42	£163,800
Existing embankment excavation	-	5,505 m^3	£81	£448,437
Keithhall Road flood gate	-	12 m x 1.8 m	£71,000	£71,000
Canal reprofile	-	961 m	£562	£540,453
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£4,470,140

Table 7-6: Option 3 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	447	447
Capital cost	4,470	4,470
Maintenance cost	2,094	610
Total	**7,011**	**5,527**
Total incl. Optimism Bias	-	8,843

7.8 Option 4 - Hard engineering, area A undefended and lowered SoP

This option consists of the following:

Area B

- Flood embankment offset in Davidson Field, 507 m long, max height 2.35 m, total volume 11,929 m^3
- Flood embankment offset along Keithhall road and the SW WWTW, 803 m long, max height 2.00 m, total 15,695 m^3
- Concrete flood wall along the right bank of the Canal, 265 m long, average height 1.4 m, assumed piled foundations
- Flood embankment around the properties at South Lodge, 145 m long, max height 2.78 m, total volume 3,330 m^3
- Remove 5,505m^3 of existing embankment soil at Davidson Field and SW WWTW
- Install a flood gate at Keithhall road approximately 12 m wide and 1.2 m high
- Demolish weir at the Canal outlet and reprofile 961 m of Canal to a more gradual gradient
- Demolish 26.5 m^2 of existing Canal bridge
- Construction of 26.5 m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) standard of protection in Area B and on near immediate initiation of works.

Table 7-7: Option 4 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Davidson Field embankment	2.35 m	11,929 m^3	£42	£501,018
Keithhall road embankment	2.00 m	15,695 m^3	£42	£659,234
Canal flood wall	1.4 m	265 m	£5,473	£1,450,370
South Lodge embankment	2.78 m	3,330 m^3	£42	£139,860

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Existing embankment excavation	-	5,505 m^3	£81	£448,437
Keithhall Road flood gate	-	12 m x 1.2 m	£71,000	£71,000
Canal reprofile	-	961 m	£562	£540,453
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£3,860,431

Table 7-8: Option 4 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	386	386
Capital cost	3,860	3,860
Maintenance cost	1,851	539
Total	**6,097**	**4,785**
Total incl. Optimism Bias	-	7,656

7.9 Option 5 - Hard engineering, Kirkwood defended to the 1000 year

This option consists of the following:

Area A

- Flood embankment along Oldmeldrum Road, 385 m long, max height 3.38 m, total volume 11,845 m^3
- Flood embankment around properties at "Gaulds Gas", 101 m long, max height 1.43 m, total volume 1,237 m^3

Area B

- Flood embankment offset in Davidson Field, 507 m long, max height 3.32 m, total volume 22,531 m^3
- Flood embankment offset along Keithhall road and the SW WWTW, 803 m long, max height 2.81 m, total 20,591 m^3
- Flood embankment along the right bank of the Canal, 319 m long, max height 2.02 m, total volume 4,006 m^3
- Concrete flood wall along the right bank of the Canal, 212 m long, average height 1.5 m, assumed piled foundations
- Lowered Canal flood wall for final 20 m length, average height 0.9 m, assumed piled foundations
- Flood embankment around the properties at South Lodge, 170 m long, max height 2.98 m, total volume 3,900 m^3
- Remove 5,505m^3 of existing embankment soil at Davidson Field and SW WWTW
- Install a flood gate at Keithhall road approximately 12 m wide and 1.8 m high
- Flood embankment at Kirkwood, 240 m long, max height 2.63 m, total volume 7,443 m^3
- Demolish 26.5 m^2 of existing Canal bridge
- Construction of 26.5 m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) standard of protection and 0.1% AP (1000 year) standard of protection at Kirkwood and on near immediate initiation of works.

Table 7-9: Option 5 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.38 m	11,845 m^3	£42	£497,490
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	3.32 m	22,531 m^3	£42	£946,365
Keithhall road embankment	2.81 m	20,591 m^3	£42	£864,880
Canal embankment	2.02 m	4,006 m^3	£42	£168,252
Canal flood wall	1.5 m	212 m	£5,473	£1,160,296
Lowered Canal flood wall	0.9 m	20 m	2,431	£48,621
South Lodge embankment	2.98 m	3,900 m^3	£42	£163,800
Existing embankment excavation	-	5,505 m^3	£81	£448,437
Keithhall Road flood gate	-	12 m x 1.8 m	£71,000	£71,000
Kirkwood embankment	2.63 m	7,443 m^3	£42	£312,606
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£4,783,760

Table 7-10: Option 5 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	478	478
Capital cost	4,784	4,784
Maintenance cost	2,246	654
Total	**7,508**	**5,916**
Total incl. Optimism Bias	-	9,466

7.10 Option 6 - Hard engineering, assumed soil reuse and SW WWTW unprotected

This option consists of the following:

Area A

- Flood embankment along Oldmeldrum Road, 385 m long, max height 3.38 m, total volume 11,845 m^3
- Flood embankment around properties at "Gaulds Gas", 101 m long, max height 1.43 m, total volume 1,237 m^3

Area B

- Flood embankment offset in Davidson Field, 400 m long, additional max height 1.71 m to the existing embankment, total additional volume 6,185 m^3
- Flood embankment offset along Keithhall road and the SW WWTW, 360 m long, additional max height 2.50 m to the existing embankment, total additional volume 5,639 m^3
- Flood embankment along the right bank of the Canal, 319 m long, max height 2.04 m, total volume 4,012 m^3
- Concrete flood wall along the right bank of the Canal, 212 m long, average height 1.6 m, assumed piled foundations
- Lowered Canal flood wall for final 20 m length, average height 0.9 m, assumed piled foundations
- Flood embankment around the properties at South Lodge, 170 m long, max height 2.98 m, total volume 3,900 m^3

- Remove 2,108m^3 of existing embankment soil around the SW WWTW
- Install a flood gate at Keithhall road approximately 12 m wide and 1.8 m high.
- Flood embankment at Kirkwood, 240 m long, max height 2.63 m, total volume 7,443 m^3
- Demolish 26.5 m^2 of existing Canal bridge
- Demolish 95.5 m^2 of listed bridge, enabling costs include additional £15,000 to account for administration costs of listed structure
- Construction of 26.5m^2 timber footbridge

Costs are based on achieving a 0.5% AP (200 year) standard of protection in Area B and 0.1% AP (1000 year) standard of protection at Kirkwood and on near immediate initiation of works.

Table 7-11: Option 6 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.38 m	11,845 m^3	£42	£497,490
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	1.71 m	6,185 m^3	£42	£259,770
Keithhall road embankment	2.50 m	5,639 m^3	£42	£236,838
Canal embankment	2.02 m	4,006 m^3	£42	£168,252
Canal flood wall	1.5 m	212 m	£5,473	£1,160,296
Lowered Canal flood wall	0.9 m	20 m	2,431	£48,621
South Lodge embankment	2.98 m	3,900 m^3	£42	£163,800
Existing embankment excavation	-	2,109 m^3	£81	£170,829
Keithhall Road flood gate	-	12 m x 1.8 m	£71,000	£71,000
Kirkwood embankment	2.63 m	7,443 m^3	£42	£312,606
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge removal	-	95.5 m^2	£64	£6,112
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£3,197,627

Table 7-12: Option 6 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	335	335
Capital cost	3,198	3,198
Maintenance cost	1,826	532
Total	**5,359**	**4,065**
Total incl. Optimism Bias	-	6,504

7.11 Summary of whole life costs

Table 7-13 summarises all Present Value costs for all of the short-listed options:

Table 7-13: Summary of PV costs for all options

Option	PV Cost (£k)
Option 1 - Hard engineering to high SoP plus climate change	11,837
Option 2 - Hard engineering to high SoP	9,984
Option 3 - Hard engineering, Area A undefended	8,843

Option	PV Cost (£k)
Option 4 - Hard engineering, Areas A undefended and lowered SoP	7,656
Option 5 - Hard engineering, Area A direct defences and Kirkwood defended to the 1000 year	9,466
Option 6 - Hard engineering, Area A direct defences , assumed soil reuse and SW WWTW unprotected	6,504

8 Benefit-cost analysis

8.1 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 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 Minimum scenarios. The benefits of any particular Do Minimum option can then be calculated by deducting the Do Minimum damages from the Do Nothing damages.

8.2 Benefit-cost results

The benefit cost results for the shortlisted options are provided in the Table 8-1.

Table 8-1: Benefit cost ratio for options in Inverurie and Port Elphinstone (£k)

	Do Nothing	Do Min	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
PV Costs (£k)	-	-	7,398	6,240	5,527	4,785	5,916	4,065
Optimism Bias (60%)	-	-	4,439	3,744	3,316	2,871	3,550	2,439
Total PV Costs (£k)	-	-	11,836	9,984	8,843	7,656	9,465	6,503
PV damage (£k)	13,421	10,557	2,465	4,062	4,103	4,103	1,309	1,234
PV damage avoided (£k)	-	2,865	10,956	9,359	9,318	9,318	12,112	12,188
Net present value (£k)	-	-	-880	-624	476	1,662	2,647	5,685
Benefit-cost ratio	-	-	0.93	0.94	1.05	1.22	1.28	1.87

The results show that in general costs are lower than the damages from the do nothing scenario. Option 6 is a future consideration which is described in more detail in section 5.12. Excluding this option, Option 5 has the most favourable benefit cost ratio of 1.28 due to the reduction in residual risk which is described in the next section. This is a good return on investment where high damages result in not only a positive BCR but a net present value of £2,647,000 avoided over the appraisal period.

8.3 Residual risks

As highlighted above residual risk is a key factor to achieving a strong positive benefit cost ratio. This is due to properties already having a high SoP where damages start to become extremely large in the later events, particularly the 0.1% AP (1000 year) and infinity year which are included in 100 year appraisal period with very low probabilities. The damages are large which results in low probabilities not cancelling out high residual risk. Key beneficiaries to this residual risk are non-residential properties which tend to incur large damages such as Kirkwood Commercial Park and the industries alongside Keithhall Road. The only solutions to minimise residual risk and ensure sustainability of the flood scheme is to either protect all properties to a minimum of 0.5% AP (200 year) plus climate change; though this incurs large costs, or to defend Kirkwood Commercial Park to the 0.1% AP (1000 year) event while still raising the SoP of the rest of the areas to 0.5% AP (200 year).

8.4 Variations on options

Options 5 and 6 are likely to be taken forward as the recommended options due to the sustainability, environmental and social benefits and close to unity BCR they have produced. Slight variations on these options have been reviewed in order to examine the best option to conclude on.

8.4.1 Option 5b

Option B5b - Direct defences on existing alignment, flood gate, canal bridge (listed bridge retained) and weir removal

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change in area B and 0.1% AP (1000 year) to the Old Mill at Kirkwood through construction of direct defences, a flood gate and existing structure removal. All information other than the description are identical to option B3a, the changes in geometry for this option are as follows:

- Construct an embankment realigned along the southern edge of Davidson Field for a length of 507 m with a maximum height of 3.94 m and an embankment defence level of 56.81 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 28.64 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are on Riverside Park where the lowest property has a threshold of 54.26 mAOD therefore the relative height of the embankment from this property is 2.55 m.
- Construct an embankment realigned along the left bank of the River Don at Keithhall Road for a length of 803 m cutting in south of the wastewater treatment works. The embankment has a maximum height of 3.24 m and an embankment defence level of 55.35 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.44 m using a 5 m crest and 1 in 3 slopes as per B1a there is adequate space for this footprint. The main properties impacted by this option are the residential properties on Keithhall Road where the lowest property has a threshold of 53.47 mAOD therefore the relative height of the embankment from this property is 1.88 m.
- Construct an embankment along the right bank of the Canal from the B993 to the northern end of Canal View for a length of 319 m. The embankment has a maximum height of 2.08 m and an embankment defence level of 55.17 mAOD including a 0.6 m freeboard.
- Construct a flood wall along the right bank of the Canal adjacent to Canal View for a length of 232 m. The wall has a maximum height of 2.05 m and a defence level of 54.87 mAOD including a 0.3 m freeboard.
- Construct an embankment around the properties at South Lodge for a length of 170 m. The embankment has a maximum height of 3.28 m and an embankment defence level of 54.90 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 24.68 m using a 5 m crest and 1 in 3 slopes as per B1a there are areas of limited space where the embankment width may need to be reassessed.
- Construct an embankment at the Canal outlet within Kirkwood Commercial Park for a length of 240 m. The embankment has a maximum height of 2.63 m and an embankment defence level of 55.39 mAOD including a 0.6 m freeboard. The embankment has a maximum width of 20.78 m using a 5 m crest and 1 in 3 slopes, from initial investigation there is enough space for this embankment though slopes or crest width may need to be re-evaluated at detailed design. The embankment position has been chosen to protect the Old Mill structure as offset from the channel as possible where it extends to the point that the natural floodplain

in Kirkwood remains in flood both to the North and South but no longer enter the building.

- Remove 5505 m^3 of existing embankment at Davidson Field and Scottish Water. Material assumed to be not suitable for new embankment as it has historically breached therefore the material has been designated for waste.
- Install a flood gate approximately 12 m wide and 2.3 m high across Keithhall Road under the railway bridge to be manually operated with the flood warning scheme currently in place.
- Demolish the footbridge bridge on the Canal directly downstream of the railway bridge. The small footbridge will be replaced by a new wooden footbridge to be designed with a similar footprint but higher soffit to convey more flow and allow for the continued access by residents.

Option 5 has been costed to protect the areas to 0.5% AP (200 year) as well as protecting the Old Mill structure at Kirkwood to 0.1% AP (1000 year) in order to increase sustainability of the scheme by reducing the residual risk. Option 5 currently prices for offset embankments which will be retained for optimal sustainability. For Option 5b a consideration has been made to the cost of Option 5 but raising the SoP to 0.5% AP (200 year) plus climate change which has been priced below which includes Option A1a and B5b above.

Table 8-2: Option 5b - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.76 m	14,888 m^3	£42	£625,296
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	3.94 m	30,408 m^3	£42	£1,277,221
Keithhall road embankment	3.24 m	28,655 m^3	£42	£1,203,590
Canal embankment	2.08 m	5,428 m^3	£42	£227,976
Canal flood wall	1.7 m	232 m	£5,473	£1,269,758
South Lodge embankment	3.28 m	4,833 m^3	£42	£202,986
Existing embankment excavation	-	5,505 m^3	£81	£448,437
Keithhall Road flood gate	-	12 m x 2.3 m	£169,000	£169,000
Bridge removal	-	26.5 m^2	£64	£1,696
Kirkwood embankment	2.63 m	7,443 m^3	£42	£312,606
Bridge construction	-	26.5 m^2	£1825	£48,363
			Total Capital cost	£5,838,883

Table 8-3: Option 5b - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	584	584
Capital cost	5,839	5,839
Maintenance cost	2,267	660
Total	**8,690**	**7,083**
Total incl. Optimism Bias	-	11,333

8.4.2 Option 6b

Option 6 has been costed to protect the areas to 0.5% AP (200 year) as well as protecting Kirkwood to 0.1% AP (1000 year) in order to increase sustainability of the scheme by reducing the residual risk. Option 6 has been priced based on the existing embankment alignments in order to optimise cost efficiency, adapting the embankments rather than removing them. For Option 6b a consideration has been made to allow for the embankments to be set back to increase sustainability and RBMP benefits, this change has been priced below.

Table 8-4: Option 6b - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost (Rounded)	Total Cost (Rounded)
Oldmeldrum Road embankment	3.38 m	11,845 m^3	£42	£497,490
"Gaulds Gas" embankment	1.43 m	1,237 m^3	£42	£51,954
Davidson Field embankment	3.32 m	21,452 m^3	£42	£900,984
Keithhall road embankment	2.56 m	13,912 m^3	£42	£584,304
Canal embankment	2.02 m	4,006 m^3	£42	£168,252
Canal flood wall	1.5 m	212 m	£5,473	£1,160,296
Lowered Canal flood wall	0.9 m	20 m	2,431	£48,621
South Lodge embankment	2.98 m	3,900 m^3	£42	£163,800
Keithhall Road flood gate	-	12 m x 1.8 m	£71,000	£71,000
Kirkwood embankment	2.63 m	7,443 m^3	£42	£312,606
Bridge removal	-	26.5 m^2	£64	£1,696
Bridge construction	-	26.5 m^2	£1,825	£48,363
			Total Capital cost	£4,009,366

Table 8-5: Option 6b - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	401	401
Capital cost	4,010	4,010
Maintenance cost	1,993	580
Total	**6,404**	**4,991**
Total incl. Optimism Bias	-	7,986

8.4.3 Variation benefit-cost analysis

Table 8-6: Benefit cost ratio for options in Inverurie and Port Elphinstone (£k)

	Do Nothing	Do Minimum	Option 5b	Option 6b
PV Costs (£k)	-	-	7,083	4,991
Optimism Bias (60%)	-	-	4,250	2,994
Total PV Costs (£k)	-	-	11,332	7,985
PV damage (£k)	13,421	10,557	697	1,234
PV damage avoided (£k)	-	2,865	12,724	12,187
Net present value (£k)	-	-	1,392	4,203
Benefit-cost ratio	-	-	1.12	1.53

The cost deviation to include climate change into the SoP of Option 5b is £11,332k which has increased by £2,647k from the original option (Option 5). This would drop the net present value to £1,392k and hence the BCR would drop to 1.12, from 1.28. From a sustainability point of view this is the best option as it accounts for climate change while also giving the lowest residual risk, avoiding the highest amount of damages while still achieving a positive BCR therefore is a more beneficial option.

Under Option 6b the change in cost from increasing the embankment length to reduce RBMP impacts and increase sustainability is £1,482k higher. Though the cost is higher the BCR still remains positive at 1.53, down from 1.87, with a net present value of £4,203k. This option should be taken forward ahead of Option 6 as offsetting the embankments is more beneficial environmentally while still obtaining a positive BCR.

9 Scheme Impact on Water Levels

Option 5b has been recommended as the preferred option, where the option is described in more detail in Section 8.4.1. Any changes in water level from the scheme using the 0.5% AP (200 year) event have been outlined in Figure 9-1 to Figure 9-4 below.

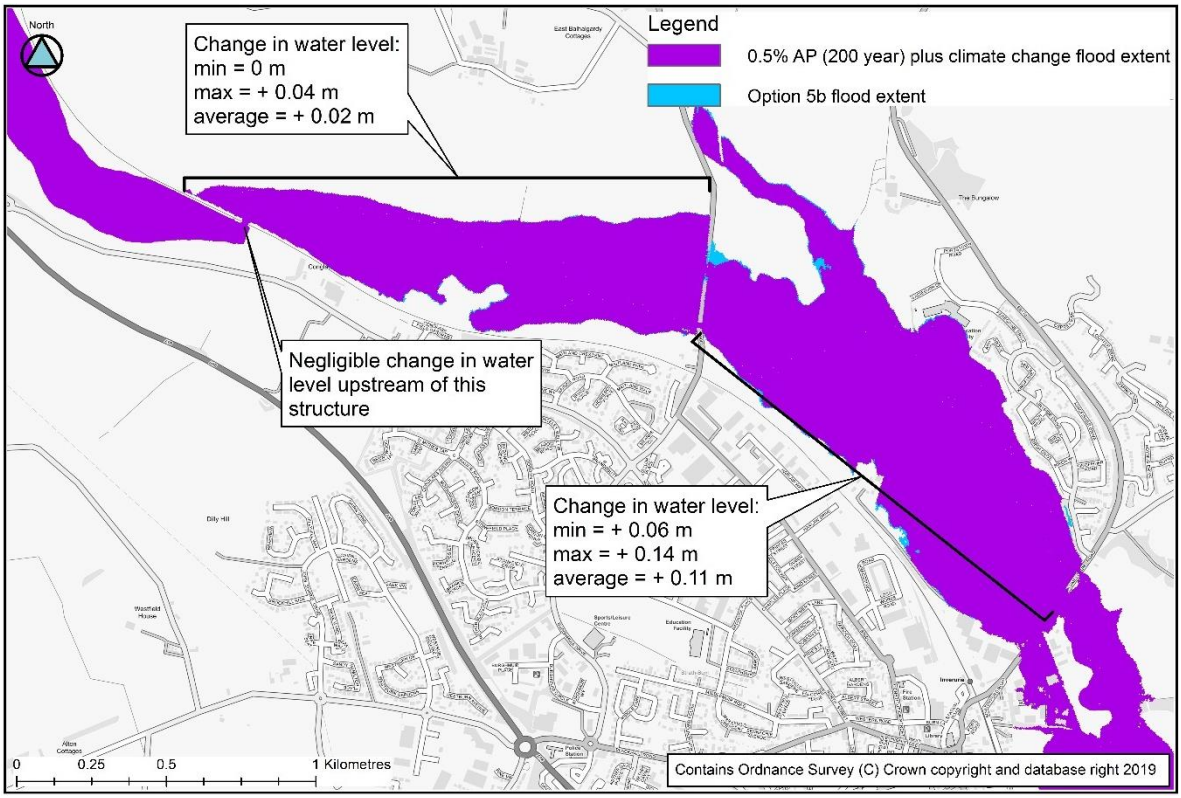


Figure 9-1: Change in water level around Oldmeldrum Road

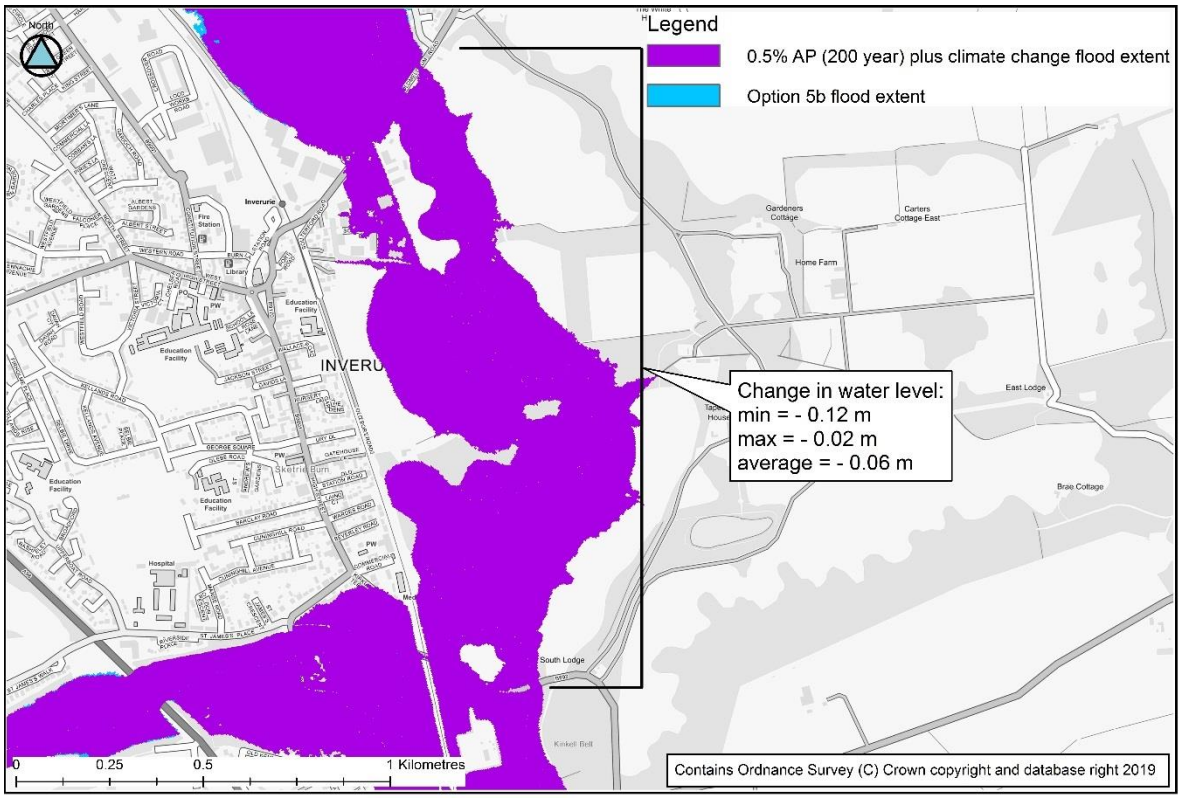


Figure 9-2: Change in water level downstream of Oldmeldrum Road

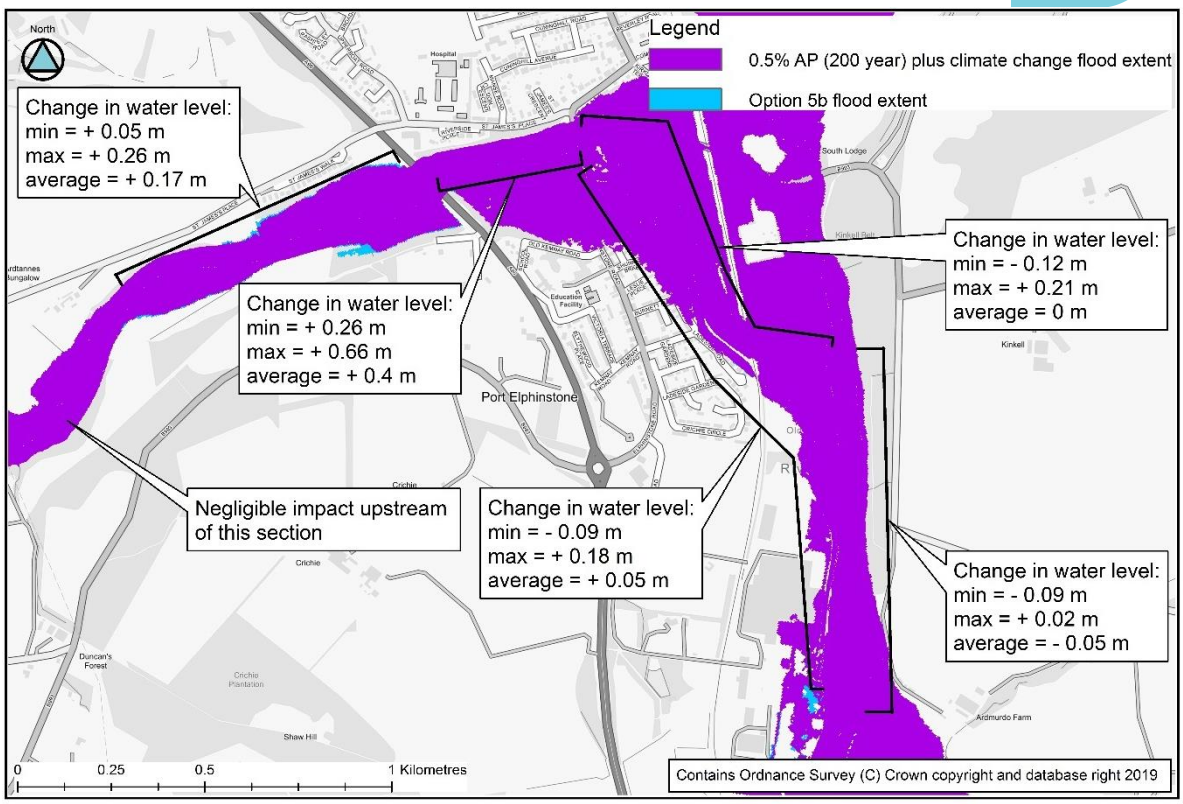


Figure 9-3: Change in water level around Port Elphinstone

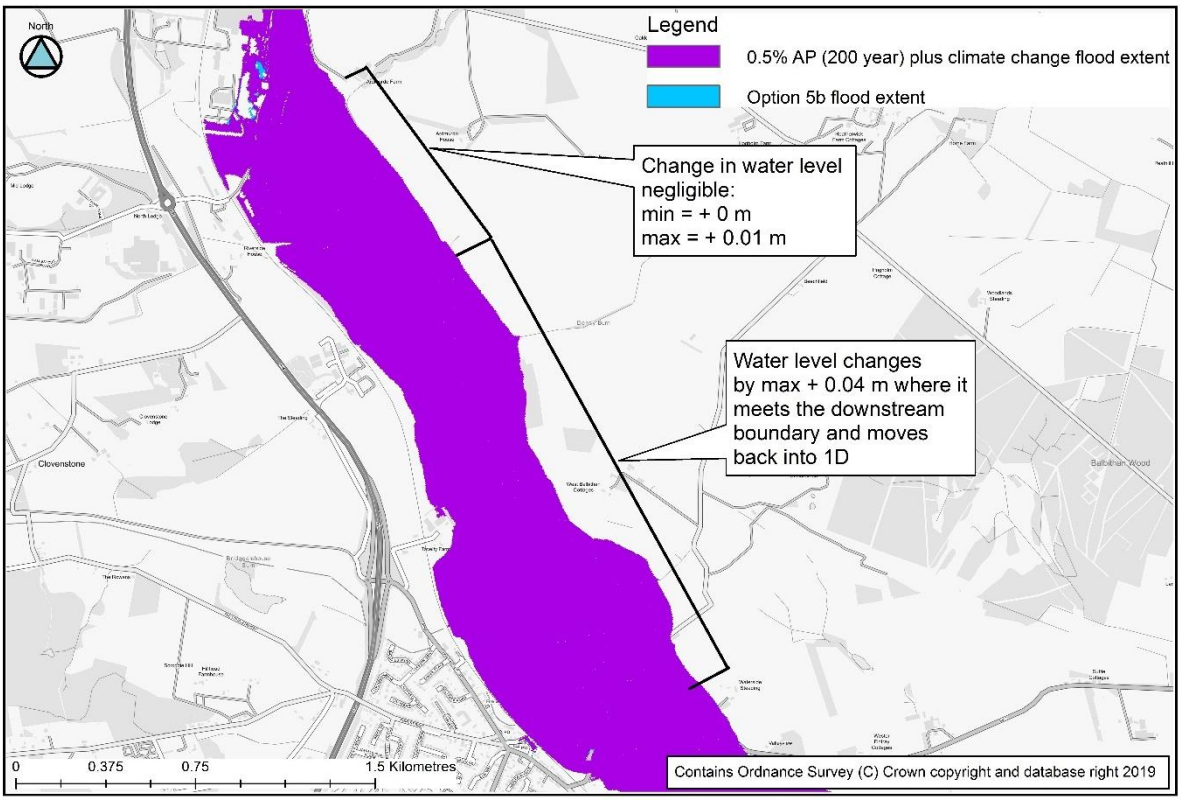


Figure 9-4: Change in water level downstream of scheme

Figure 9-1 to Figure 9-4 show that the scheme changes the water levels in different locations. The water levels balance out almost immediately upstream of the scheme on the River Urie and increase behind Souterford bridge at Oldmeldrum Road as expected. Downstream of the bridge on the Urie, the water levels drop. The water levels change often around Port Elphinstone from decrease around the confluence between the Urie and the Don to an increase at the Elphinstone Road bridge. The bridge has been highlighted as requiring further investigation from this increase through a detailed scour assessment, though during current conditions the bridge already has its soffit breached therefore this assessment is recommended regardless. The water levels again balance out upstream on the Don roughly a kilometre from the A96 road bridge. The water levels also balance out almost immediately downstream of the Scheme towards Kintore where a minor rise is observed due to the downstream boundary condition in the model.

10 Stakeholder engagement

A stakeholder engagement meeting took place on 16 May 2019 in Inverurie to get a better understanding of how key stakeholders respond to the options that have been proposed by this study.

The options within the different design areas were presented and the following key comments were made:

- Concern was raised over the properties within "Gaulds Gas", location shown on Figure 5-7, as to whether they were at flood risk. The properties are not at risk unless Area A is protected which includes a direct defence to protect these properties.
- There was discussion of a future redesign of the road bridge B9001 which could create storage upstream on the River Urie. This option has been tested for feasibility within the appraisal study.
- It was noted that some Canal structures and the Canal may be listed. A further check showed that one of the structures is listed which has been included in the costing analysis.
- It was highlighted that there are a number of Invasive Non-native Species in the area which should be commented on in the study.

A further discussion was made via telecon with Scottish Water where the following key points were added:

- Scottish Water queried if there was reverse flow up the Canal.
- It was discussed whether demolition of the older site to the west would be conducted in the near future, this is still to be confirmed.

11 Public engagement

A public engagement event was held in Inverurie on 8 October 2019 to gauge public opinion on the flood mitigation options proposed as part of this study. Approximately 38 residents attended the event and many offered their views on the options proposed. Feedback was largely positive and of the residents who attended the breakdown of attendance from area A and area B was as follows:

- Area A (Oldmeldrum Road) - 6
- Area B (Port Elphinstone & South Inverurie) - 15
- Other / unknown areas - 17

The overall feedback was provided for each area based on the above attendance through both verbal conversations and returned written feedback forms:

- **Area A (Oldmeldrum Road):** The feedback from the event and questionnaires was largely positive with all options in this area predominantly scoring a 5 where there were also a couple of 4's with nothing lower than a 3. In particular, the businesses in Souterford were extremely positive in regards to the preferred option of a bund within this area. They noted that it will not only protect their properties but attenuate flow to aid with lowering levels downstream. A few residents were concerned with the rise in water levels behind Oldmeldrum Road though were content that this had been investigated in the modelling and has been reinforced by a bund at Gauld's Gas due to the slight detrimental effect.
- **Area B (Port Elphinstone & South Inverurie):** The feedback from the event and questionnaires was largely positive with the majority of the scores either 5 or 4 with no responses lower than a 3. Most residents were impressed with setting the embankments back though it has been expressed that setting back the Davidson Field embankment requires some thought over the currently limited parking and access to the field from the Pavilion. This requires consideration during detailed design, particularly as one resident explained that the edge of the field is used on matchday for parking which would be blocked by the new embankment if not correctly designed. Residents were happy with the Canal defences and were assured that the footpath was to be retained though there were numerous responses as to the current condition of the Canal itself. Many residents expressed concern over the filling of one of the Canal channels when Kirkwood dredged one channel and put the material into the other, the general belief is that this requires action and the channel should be lowered due to increasing flood risk to their properties. Maintenance of all watercourses is recommended by this study where the model assumes flow down this channel. The flood gate on Keithhall Road was generally well received where any concern over the height has been further assessed, analysed and re-checked against the 2016 post flood levels recorded. The requirements at detailed design stage for consideration of the drainage system and its influence on flooding was also discussed with the residents.

Feedback on the preferred option (Option 5b) was also gauged in the questionnaire with all responses giving it a 5 other than a single response which gave it a 4.

12 Conclusions and recommendations

12.1 Summary

This report presents the results of a detailed flood risk appraisal for the communities of Inverurie and Port Elphinstone, focussing on the risk from both the River Don and the River Urie. There has been an extensive flood history within the area of Inverurie and Port Elphinstone with a particularly extreme event in 2016 which has been calculated to be roughly equivalent to a 1% AP (105 year) event at Haughton gauging station on the River Don see Figure 1-1, furthermore the 2016 event is the largest on record (1983 to present). During this event the existing defences around South Inverurie and Port Elphinstone breached which became a key contributor to the flooding. The optioneering has looked at protecting the properties within the study area to 0.5% AP (200 year) with an allowance of an additional 24% for climate change. During the Do Minimum scenario which represents conditions experienced today 138 properties are at risk from the 0.5% AP (200 year) plus climate change event.

A detailed set of preliminary investigations was carried out in precedence to this appraisal such that it was possible to inform discussion of flood protection options for Inverurie and Port Elphinstone. These investigations involved a review of the areas flood history, an assessment of the hydrological inputs to the watercourses studied, collection and review of survey data, a review of the potential for Natural Flood Management, a Preliminary Ecological Appraisal, asset condition assessment and hydraulic modelling of the watercourses.

The hydraulic model, consisting of a 1D/2D Flood Modeller and TUFLOW model covering an area from upstream of Old Rayne to downstream of Kintore, 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 Inverurie and Kintore's flood risk problem. A feasibility analysis was conducted on a number of options which were likely to be unrealistic, any feasible options were taken forward into the shortlist appraisal.

Inverurie and Port Elphinstone was split into 2 different design areas to tackle the flood risk based on differing flood mechanisms, after extensive review of the shortlisted options the following options for each design area were taken forward where different combinations were analysed to reach a preferred solution:

- **Design area A - Oldmeldrum Road**
    - Direct defences;
        - Along Oldmeldrum Road around the retail park.
        - Around the "Gaulds Gas" properties on the floodplain, location shown on Figure 5-7.
- **Design area B - South Inverurie and Port Elphinstone**
    - Removal of some of the structures crossing the canal.
    - Increase existing embankments at Davidson Field and Scottish Water treatment works, both in offset positions and existing positions.
    - Embankment and walls on right bank of the canal.
    - Embankment around the properties at South Lodge.
    - Flood gate on Keithhall Road under the rail bridge.
    - Modification around the canal outlet;
        - Removal of the canal weir outlet.
        - Embankments around canal outlet.

A benefit-cost analysis has been undertaken for the present-day (Do Minimum) scenario and each of the above options. Costs for each option have been estimated using the Environment Agency's Long Term Costing tool (2012). An optimism bias factor of 60 % has been added to the total capital costs to allow for uncertainties in design at this level of appraisal and is typical for schemes at an early stage of appraisal.

12.2 Additional information and regulation requirements

If an option is taken forward the additional information outlined in the option descriptions in Section 5.8 should be addressed. As well as this the following regulations should be adhered to alongside all options:

- Should any options be taken forward the SEPA local regulatory team should be promptly contacted to discuss the design proposals in order to aid with completion of an environmental standards test to show how the works will not cause deterioration to any of the watercourse statuses.
- A future assessment will likely be required to investigate the morphological impact of the option and if any impacts can be further mitigated.
- Continued engagement with the Fisheries Board is advised to ensure the desired proposal does not impact fish spawning habitats.
- A Controlled Activities Regulations (CAR) construction site licence will be required for management of surface water run-off from a construction site, including access tracks, which:
    - Is more than 4 hectares,
    - Is in excess of 5 km, or
    - Includes an area of more than 1 hectare or length of more than 500 m on ground with a slope in excess of 25˚.
- It is strongly encouraged that pre-CAR application engagement with a member of the regulatory services team is made as early as possible.
- Below the thresholds listed above will need to comply with the CAR general binding rule 10[15] which requires, amongst other things, that all reasonable steps must be taken to ensure that the discharge does not result in pollution of the water environment.

12.3 Recommendations

The above analysis resulted in the following key recommendations for Inverurie and Port Elphinstone:

Option 5 and the variation of the option discussed in section 8.4 (Option 5b) should be considered further as they achieve the most sustainable Standard of Protection while also considering environmental and social benefits and, achieving a positive BCR (1.28 and 1.12 respectively).

Option 5b would be the preferred option (BCR of 1.12) as it provides the most sustainable solution with the least amount of residual risk, achieving a SoP of 0.5% AP (200 year) with the inclusion of climate change. It also includes additional benefits such as improving RBMP by further offsetting the existing embankments as well as social opportunities of formalising floodplain green space and making the canal walkways safer. It is important to note that while 5b protects the Old Mill at Kirkwood to the 0.1% AP (1000 year) these measures are not established to facilitate development of an area which under SPP lies partially within the functional floodplain. It is understood the development of the commercial park is ongoing, and any future development would need to consider the existing flood risk with respect to requirements for land raising, compensatory storage, finished floor levels and, access and egress. In addition under Option 5b there are areas of the commercial park which remain at flood risk, and hence development within these areas should be avoided.

Watercourse maintenance has been recommended alongside all options, consideration into the maintenance of the Old Canal may need to be further investigated where it is understood after public engagement one of the channels may have been partially filled. The model assumes full flow down both channels of the Canal.

Options 3 and 4 achieve a positive BCR but should be discounted as they leave Area A undefended. This would not be acceptable from the perspective of the larger community as it would be excluding selective properties. If Option 5b is not taken forward a future option, Option 6 and 6b have been reviewed as they achieve a high BCR. The Scottish Water wastewater treatment works has been redeveloped on the eastern side of the railway. When considering the full 100 year appraisal period there is the potential option for the older part of the site (west of the railway line) to be demolished, completing relocation of the area. Option 6 shows how relocating this area can achieve a high BCR

15 SEPA, The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended), A Practical Guide, Version 8.3, February 2019

due to the reduction in embankment length required, while further increasing the River Don floodplain though this option also relies on the reuse of the existing embankment soil. Both reuse of the existing embankment soil and allowing the Don to flood on this site are future options which are recommended for investigation if the site is abandoned.

The area of Port Elphinstone is located on the site of the Old Canal pond, therefore it sits within a depression. Issues with flooding occurring when river levels are high (but not out of bank) is a known problem. It is recommended that the previous drainage study which was conducted in Port Elphinstone[16] be revisited if an FPS is put into place to protect the properties within Port Elphinstone. The report recommended the possibility for a flap valve on the outlet of the drainage pipes into the River Don due to drainage issues only arising when the outlet is submerged as the capacity of the network is adequate.

Due to the high costing of the structured options investigation into the effectiveness of implementing more Natural Flood Management (NFM) into the area could be beneficial. The preliminary investigation highlighted multiple areas where NFM could be utilised well, in particular on the tributaries such as the Ton Burn to reconnect more of the watercourses with their floodplain.

16 2003 - Port Elphinstone Drainage Study, EnviroCentre

Appendices

A Appendix A - Damage Methodology

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 A-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 the difference in the areas beneath the curve is the annual reduction in flood losses to be expected from the scheme or mitigation approach.

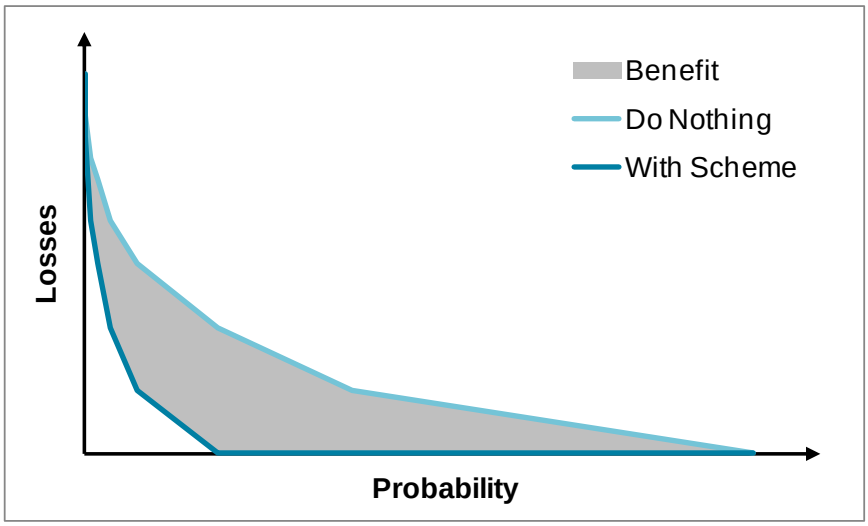


Figure A-1: Loss Probability Curve

To derive these two curves, straight lines are drawn between the floods for which there are 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 threshold levels.

A flood damage estimate was generated using JBA's in-house flood damage tools. These estimate 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 buildings floor area) flood damage estimates have been calculated and are presented in section 6.2.

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

Table A-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 2017 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. 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 Inverurie and Port Elphinstone were obtained from the Scottish Assessors Association website[17]. Equivalent yield varies regionally and temporarily, but is recommended to be a value of 10-12.5 for flood defence purposes[18]. A value of 12.5 was used.

However, the resulting property valuations were judged as being undervalued. An alternative approach was used whereby the estimated value is 3 times the max depth damage MCM curve damage value for the commercial property type multiplied by the properties ground floor area.

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

A.1.4 Updating of Damage Values

The MCM data used are 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[19] 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.

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

B Appendix B - Economic Appraisal

Inverurie & Port Elphinstone Final Options Benefit Cost Summary

Client/Authority						Prepared (date)			02/07/2019
Aberdeenshire Council						Printed			21/10/2019
Project name						Prepared by			DS
Ellon, Inverurie & Insch FPS						Checked by			AP
Project reference	2017s6743					Checked date			28/08/2019
Base date for estimates (year 0	Jan-2019								
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 facto	60%								
Costs and benefits of options									

Option number	**Costs and benefits £k**							
	Do-nothing	**Do-minimum**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Option name	Do-nothing	Do-minimum	A - Direct defences B - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal (200CC)	A - Direct defences B - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal	A - Undefended B - Direct defences, flood gate, canal bridge removal	A - Undefended B - Direct defences on existing alignment, flood gate, canal bridge and weir removal	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000)	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000) Scottish Water undefended, soil reused
AEP or SoP (where relevant)	20% AP (5 year)	3.33% AP (30 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	Area A 3.33% AP (30 year) Area B 0.5% AP (200 year)	Area A 3.33% AP (30 year) Area B 1% AP (100 year)	Area A 0.5% AP (200 year) Area B 0.5% AP (200 year) Kirkwood 0.1% AP (1000 year)	Area A 0.5% AP (200 year) Area B 0.5% AP (200 year) Kirkwood 0.1% AP (1000 year)
COSTS:								
PV capital costs	0	0	6,067	5,020	4,470	3,860	4,784	3,196
PV operation and maintenance cost	0	0	724	718	610	539	654	532
PV Enabling	0	0	607	502	447	386	478	335
Optimism bias adjustmen	0	0	4,439	3,744	3,316	2,871	3,550	2,439
PV negative costs (e.g. sales	0	0	0	0	0	0	0	0
PV contributions								
Total PV Costs £k excluding contributions	0	0	11,836	9,984	8,843	7,656	9,465	6,503
Total PV Costs £k taking contributions into accoun	0	0	11,836	9,984	8,843	7,656	9,465	6,503
BENEFITS:								
PV monetised flood damage	13,421	10,557	2,465	4,062	4,103	4,103	1,309	1,234
PV monetised flood damages avoide		2,865	10,956	9,359	9,318	9,318	12,112	12,188
Total monetised PV damages £k	13,421	10,557	2,465	4,062	4,103	4,103	1,309	1,234
Total monetised PV benefits £k		2,865	10,956	9,359	9,318	9,318	12,112	12,188
Based on monetised PV benefits (ex cludes benefits from scoring and weighting and ecosystem services)								
Net Present Value **NPV**		2,865	-880	-624	476	1,662	2,647	5,685
Average benefit/cost ratio **BCR**			0.93	0.94	1.05	1.22	1.28	1.87
								Highest bcr
Best practicable environmental option (WFD								

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	A - Direct defences B - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal (200CC)
Option 2	A - Direct defences B - Direct defences, flood gate, canal bridge (listed bridge retained) and weir removal
Option 3	A - Undefended B - Direct defences, flood gate, canal bridge removal
Option 4	A - Undefended B - Direct defences on existing alignment, flood gate, canal bridge and weir removal
Option 5	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000)
Option 6	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000) Scottish Water undefended, soil reused

Inverurie & Port Elphinstone Final Options Benefit Cost Summary

Appendix B: Page 2

Prepared (date)	02/07/2019
Printed	21/10/2019
Prepared by	DS
Checked by	AP
Checked date	28/08/2019

Client/Authority
Aberdeenshire Council
Project name
Ellon, Inverurie & Insch FPS
Project reference 2017s6743
Base date for estimates (year 0) Jan-2019
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	**Do-nothing**	**Do-minimum**	**Option 5b**	**Option 6b**		
Option name	Do-nothing	Do-minimum	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000)	A - Direct defences B - Direct defences on set back alignment, flood gate, canal bridge removal (Kirkwood SoP 1000) Scottish Water undefended, soil reused		
AEP or SoP (where relevant)	20% AP (5 year)	3.33% AP (30 year)	Area A 0.5% AP (200 year) + climate change Area B 0.5% AP (200 year) + climate change Kirkwood 0.1% AP (1000 year)	Area A 0.5% AP (200 year) Area B 0.5% AP (200 year) Kirkwood 0.1% AP (1000 year)		
COSTS:						
PV capital costs	0	0	5,839	4,010		
PV operation and maintenance costs	0	0	660	580		
PV Enabling	0	0	584	401		
Optimism bias adjustment	0	0	4,250	2,994		
PV negative costs (e.g. sales)	0	0	0	0		
PV contributions						
Total PV Costs £k excluding contributions	0	0	11,332	7,985		
Total PV Costs £k taking contributions into account	0	0	11,332	7,985		
BENEFITS:						
PV monetised flood damages	13,421	10,557	697	1,234		
PV monetised flood damages avoided		2,865	12,724	12,188		
Total PV damages £k	13,421	10,557	697	1,234		
Total PV benefits £k		2,865	12,724	12,188		
Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		2,865	1,392	4,203		
Average benefit/cost ratio **BCR**			1.12	1.53		
Best practicable environmental option (WFD)						

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 5b	A - Direct defences B - Direct defences, flood gate, canal bridge removal (Kirkwood SoP 1000)
Option 6b	A - Direct defences B - Direct defences on set back alignment, flood gate, canal bridge removal (Kirkwood SoP 1000) Scottish Water undefended, soil reused

Option 1 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£606.67
Capital Costs	£6,066.73
O & M Costs	£2,488.72
Other Costs	£0.00
Total Real Cost	£9,162.12
Total Cost PV	£7,397.71
Total Cost PV + OB	**£11,836.34**

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:

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			£403.75	£4,037.46	£1,756.69	£0.00	£6,197.89	£4,952.47
	Wall			£126.98	£1,269.76	£12.99	£0.00	£1,409.73	£1,400.51
	Sheet Piling								
Channel management	N/A			£54.05	£540.45	£406.09	£0.00	£1,000.59	£712.68
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£16.90	£169.00	£301.07	£0.00	£486.97	£273.52
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 2 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£501.96
Capital Costs	£5,019.58
O & M Costs	£2,467.99
Other Costs	£0.00
Total Real Cost	£7,989.53
Total Cost PV	£6,239.82
Total Cost PV + OB	**£9,983.71**

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:

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			£316.44	£3,164.37	£1,737.47	£0.00	£5,218.27	£3,986.47
	Wall			£119.37	£1,193.71	£11.48	£0.00	£1,324.56	£1,316.42
	Sheet Piling								
Channel management	N/A			£54.05	£540.45	£406.09	£0.00	£1,000.59	£712.68
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 3 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£447.01
Capital Costs	£4,470.14
O & M Costs	£2,094.36
Other Costs	£0.00
Total Real Cost	£7,011.51
Total Cost PV	£5,526.69
Total Cost PV + OB	**£8,842.70**

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:

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			£261.49	£2,614.92	£1,363.83	£0.00	£4,240.25	£3,273.34
	Wall			£119.37	£1,193.71	£11.48	£0.00	£1,324.56	£1,316.42
	Sheet Piling								
Channel management	N/A			£54.05	£540.45	£406.09	£0.00	£1,000.59	£712.68
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 4 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/09/2019
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	£386.04
Capital Costs	£3,860.43
O & M Costs	£1,850.92
Other Costs	£0.00
Total Real Cost	£6,097.39
Total Cost PV	£4,785.16
Total Cost PV + OB	**£7,656.25**

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:

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			£174.85	£1,748.55	£1,118.59	£0.00	£3,041.99	£2,248.95
	Wall			£145.04	£1,450.37	£13.28	£0.00	£1,608.69	£1,599.27
	Sheet Piling								
Channel management	N/A			£54.05	£540.45	£406.09	£0.00	£1,000.59	£712.68
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 5 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£478.38
Capital Costs	£4,783.76
O & M Costs	£2,246.44
Other Costs	£0.00
Total Real Cost	£7,508.58
Total Cost PV	£5,915.93
Total Cost PV + OB	**£9,465.49**

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:

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			£345.38	£3,453.78	£1,921.98	£0.00	£5,721.14	£4,358.53
	Wall			£120.89	£1,208.92	£11.51	£0.00	£1,341.32	£1,333.16
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 5b costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£583.89
Capital Costs	£5,838.88
O & M Costs	£2,267.14
Other Costs	£0.00
Total Real Cost	£8,689.91
Total Cost PV	£7,082.59
Total Cost PV + OB	**£11,332.15**

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:

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			£435.01	£4,350.07	£1,941.20	£0.00	£6,726.27	£5,350.03
	Wall			£126.98	£1,269.76	£12.99	£0.00	£1,409.73	£1,400.51
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£16.90	£169.00	£301.07	£0.00	£486.97	£273.52
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 6 costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/08/2019
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	£334.79
Capital Costs	£3,197.88
O & M Costs	£1,826.33
Other Costs	£0.00
Total Real Cost	£5,359.00
Total Cost PV	£4,064.19
Total Cost PV + OB	**£6,502.71**

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:

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			£186.18	£1,861.79	£1,499.14	£0.00	£3,547.11	£2,484.27
	Wall			£120.89	£1,208.92	£14.24	£0.00	£1,344.05	£1,333.95
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£15.78	£7.81	£0.00	£0.00	£23.59	£23.59
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

Option 6b costs

Client/Authority		Prepared (date)	02/07/2019
Aberdeenshire Council		Printed	21/10/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	AP
Project reference	2017s6743	Checked date	28/09/2019
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	£400.96
Capital Costs	£4,009.62
O & M Costs	£1,993.16
Other Costs	£0.00
Total Real Cost	£6,403.74
Total Cost PV	£4,990.66
Total Cost PV + OB	**£7,985.06**

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			£267.96	£2,679.64	£1,665.97	£0.00	£4,613.58	£3,432.46
	Wall			£120.89	£1,208.92	£14.24	£0.00	£1,344.05	£1,333.95
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate			£7.10	£71.00	£301.07	£0.00	£379.17	£165.72
	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			£0.17	£1.70	£0.00	£0.00	£1.87	£1.87
User Defined 2	Various			£4.84	£48.36	£11.88	£0.00	£65.08	£56.66
User Defined 3	Various								

C Appendix C - Do Nothing Assumptions

C.1 Outline of the problem

Properties are at risk of flooding from both the River Urie and River Don within Inverurie and Port Elphinstone.

Assessing the level of risk for both the Do Nothing and Do Minimum options needs to consider how the watercourses will change and how any flow controlling assets or flood defences will react or deteriorate over the appraisal period. The following sections detail the assumptions used for the Do Nothing and Do Minimum options for this study.

C.2 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; cease all maintenance and repairs to the existing defences and watercourse activities. This therefore represents a scenario with no intervention in the natural process and serves as a baseline against which all other options are compared. The following recommendations are therefore used for the Do Nothing and Do minimum options.

C.3 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. Due to reasonable bank growth already observed and agricultural land which would likely continue to be maintained a +20% Manning's 'n' roughness has been applied out of bank throughout both watercourses for the entire appraisal period. Due to the Urie and Don being a large watercourses sediment build up and blockage is less likely therefore the in-bank Manning's 'n' roughness value will only be increased by 10%.

It is recommended that bridge blockage is included in the Do Nothing scenario. A full list of the structures to be blocked can be found in Section 2 which have been determined using a risk-based analysis.

C.3.1 Embankment failure

The above Do Nothing assumptions will be applied as a constant throughout the 100 year period, for the Do Nothing damages during the appraisal period full breach of the Davidson Field and Scottish Water embankments will be taken into account.

The existing embankments within Inverurie; Davidson Field embankment and the Scottish Water embankment breached during the 2016 event, while re-instated, they have a likely probability of failing during the 100 year appraisal period. The Environment Agency guidance on degradation of assets[20] was used to determine how long the embankment could last before the condition deteriorates to grade 4 (significant reduction in performance). An earth embankment with varying core material and narrow crest width (<4m wide) is the classification that best represents both of the named embankments. Due to defects resulting in reduced performance of the embankment (historical breaching) both embankments have been classified as grade 3 or in "Fair" condition. Therefore, according to the Environment Agency guidance the embankment shall reach imminent failure in 19 to 70 years, without or with maintenance respectively.

Due to the guidance above at year 0 the embankments will be represented with 0.6m freeboard removed to simulate conditions of what the defence was designed to.

At year 20 the embankments will be removed completely to simulate embankment failure.

C.4 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.

Both Davidson Field embankment and Scottish water's embankment will have a reduction of 0.6m freeboard removed to simulate conditions of what the defence was designed to.

20 Environment Agency (2013) SC060078/R1: 'Practical guidance on determining asset deterioration and the use of condition grade deterioration curves'.

C.5 Economic appraisal

For the economic appraisal the Do Nothing scenario will be used as a baseline for damages, this includes the varying Annual Average Damage (AAD) estimate at year 20 for embankment failure. This will result in a linear damage for 0-19 years, a jump to the higher damage at year 20, then a linear damage from year 20-100 with the higher damages from embankment failure.

For the options the Do Minimum assumptions will be used which includes the removal of 0.6m freeboard on the embankments.

Do Nothing Scenario

"Walk away" scenario

Assumptions:

Constants:

Increased vegetation growth on banks - Manning's 'n' +20%

Slight increase of sediment build up in channel - Manning's 'n' +10%

Blockage of structures as per the blockage scenario assessment

Year0:

0.6m freeboard subtracted from Davidson Field and Scottish Water embankments

Year 20:

Full failure of embankments, removal of both

Do Minimum Scenario

Present day scenario

Assumptions:

Present day conditions assuming continued maintenance

0.6m freeboard subtracted from Davidson Field and Scottish Water embankments

Appraisal Period

100 year economic appraisal process

Assumptions:

Baseline damages:

As per the Do Nothing scenario with a change in AAD at year 20

Optioneering damages:

As per the Do Minimum scenario with a reduction in freeboard on the embankments

C.6 Blockage Scenario

A risk based analysis for all the structures in Inverurie was carried out to determine which structures are most likely to block in a Do Nothing Scenario. The tables below show the parameters and results that were evaluated as these are the most likely to pose a risk of blockage.

The following bridges will be modelled using the following method:

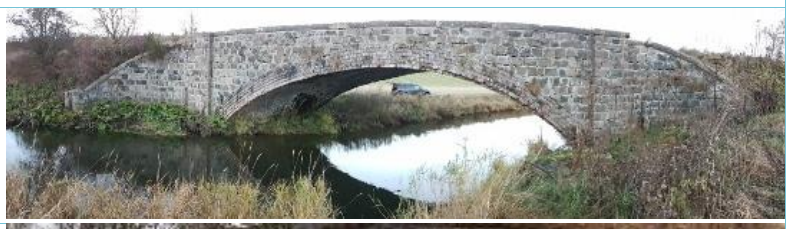
- RU_23243_BU - abutments widened by 0.2m in towards the channel.
- RU_17415_BU - abutments widened by 0.2m in towards the channel.
- RU_16880_BU - abutments widened by 0.2m in towards the channel.
- RD_23345 - Central pier has been extended by 0.5m in both directions.
- RD_22463B - Central pier has been extended by 0.5m in both directions.
- RD_1746BU - Central pier has been extended by 0.5m in both directions.
- RD_1666BU - Central pier has been extended by 0.5m in both directions.
- CAN_1419BU - Soffit level dropped by 0.2m.
- CAN_0857B - Soffit level dropped by 0.2m.

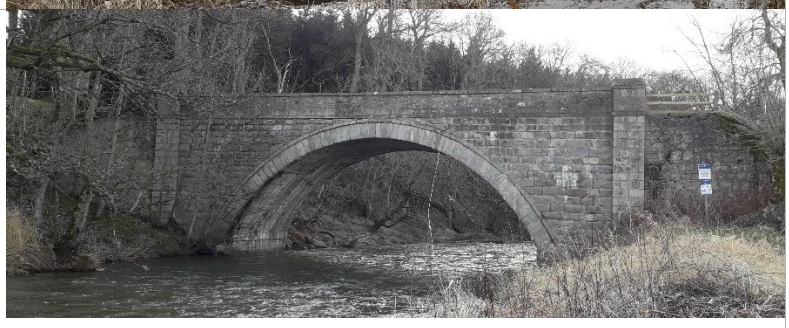
Blockage Scenario - River Urie								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream and downstream properties**	**To be included in blockage scenario**	**Explanation**
RU_23243_BU	14.38	no	no	no	Farmland / scattered woodland	no	**yes**	Smaller flow area may be prone to blockage at abutments
RU_21836_BU	31.49	no	no	no	Farmland / scattered woodland	yes	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_17415_BU	29.84	no	no	no	Woodland	no	**yes**	Prone to blockage from woodland debris
RU_16880_BU	17.47	no	no	no	Woodland	no	**yes**	Prone to blockage from woodland debris, smaller area
RU_15554_BU	20.97	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_14666_BU	48.29	no	no	no	Farmland / scattered woodland	yes	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_12997_BU	23.91	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_12806_BU	54.96	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_11031_BU	64.84	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_11003_BU	56.50	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_8843_BU	55.84	no	no	no	Farmland / scattered woodland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_6478_BU	61.40	no	no	no	Grassland / arable farmland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_4687_BU	28.18	no	no	no	Grassland / marshland	no	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_3929_BU	58.20	no	no	no	Grassland / marshland	yes	no	Large flow area with high soffit, not as vulnerable from upstream land use
RU_0507_BU	79.35	no	no	no	Marshy grassland / scattered woodland	yes	no	Large flow area with high soffit, not as vulnerable from upstream land use

Blockage Scenario - River Don								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream properties**	**To be included in blockage scenario**	**Explanation**
RD_23753	900.64	no	no	no	Grassland / some woodland	no	no	Extremely large area
RD_23345	211.15	no	no	yes	Woodland	no	**yes**	Large flow area though woodland land use and in-channel pier result in vulnerability around the pier
RD_22463B	270.87	no	no	yes	Scrub	no	**yes**	Potential for blockage around in-channel pier
RD_16017	195.84	no	no	no	Arable farmland	yes	no	Extremely large area
RD_9568_BU	197.69	no	no	no	Arable farmland	no	no	Extremely large area
RD_1746BU	282.80	no	no	yes	Grassland / some woodland	no	**yes**	Large flow area though woodland land use and in-channel pier result in vulnerability around the pier
RD_1666BU	284.46	no	no	yes	Grassland / some woodland	no	**yes**	Large flow area though woodland land use and in-channel pier result in vulnerability around the pier

Blockage Scenario - Canal								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream properties**	**To be included in blockage scenario**	**Explanation**
CAN_1419BU	12.38	no	no	no	Scrub / grassland	yes	**yes**	Small flow area prone to blockage
CAN_0898B	50.11	no	no	no	Scrub / grassland	yes	no	Large flow area with high soffit
CAN_0857B	16.43	no	no	no	Scrub / grassland	yes	**yes**	Small flow area with low soffit

Section Number and Bridge Name	Structure Unit Type	Photo
River Urie (RU)		
RU_23243 Farm Access Road Bridge NGR NJ 66536 29185	Arch Bridge	
RU_21836 Lawrence Road Bridge NGR NJ 67225 28214	Arch Bridge	
RU_17415 Road Bridge at Logie Country House NGR NJ 69971 25780	USBPR Bridge	
RU_16880 Foot Bridge at Logie Country House NGR NJ 70479 25777	USBPR Bridge	

RU_15554 Unnamed Foot Bridge NGR NJ 71626 25644	USBPR Bridge	
RU_14666 Road Bridge at Whiteford NGR NJ 72159 25933	Arch Bridge	
RU_12997 Unnamed Foot Bridge NGR NJ 73171 25921	USBPR Bridge	
RU_12806 Unnamed Foot Bridge NGR NJ 73314 25799	Arch Bridge	
RU_11031 Railway Bridge at Milton of Inveramsay NGR NJ 74149 24673	Arch Bridge	
RU_11003 Road Bridge at Milton of Inveramsay NGR NJ 74132 24653	Arch Bridge	
RU_8843 ANI1 293/077 Railway Bridge Conglass	Arch Bridge	

NGR NJ 75164 82334		
RU_6478 Howford Bridge B9001 NGR NJ 76683 22991	Arch Bridge	
RU_4687 Park Footbridge at Birch Drive NGR NJ 77767 22534	Arch Bridge	
RU_3929 Souterford Road Bridge B9170 NGR NJ 77951 22183	USBPR Bridge	
RU_0507 Keithhall Road Bridge B993 NGR NJ 78264 20522	Arch Bridge	
River Don		
RD_23753 A96 Road Bridge[21] NGR NJ 77229 20499	USBPR Bridge	

21 New A96 dual carriageway route design currently under consideration. Consideration for compensatory storage for the road which may impact on the existing flood risk areas and potential FPS option.

RD_23345 B996 Elphinstone Road Bridge NGR NJ 77617 20629	USBPR Bridge	
RD_22463 ANI1 293/068 Railway Bridge Port Elphinstone 22 NGR NJ 78081 20062	USBPR Bridge	
RD_16017 B977 Road Bridge Kintore NGR NJ 79618 16208	USBPR Bridge	
RD_9568 B979 Road Bridge Near Hatton of Fintray NGR NJ 83728 15900	Arch Bridge	
RD_1746 Parkhill Foot Bridge Dyce NGR NJ 88827 14165	USBPR Bridge	
RD_1666 A947 Parkhill Road Bridge Dyce NGR NJ 88895 14124	USBPR Bridge	
Canal		

22 New Aberdeen to Inverness railway line duelling and upgrade currently under consideration. Crossing realignment and new crossing may be likely at this location.

CAN_1419 Old Canal Footpath Bridge NGR NJ 77806 20395	USBPR Bridge, Left side blocked as per bottom picture. The spill unit allows for slight seepage	 
CAN_0898 Railway Bridge over canal NGR NJ 78099 19989	USBPR Bridge	
CAN_0857 Old Canal Footpath Bridge NGR NJ 78133 19958	USBPR Bridge	

CAN_0000 Weir at Kirkwood Commercial Park NGR NJ 78279 19169	Weir modelled as a spill unit 1.4 Spill coefficient		

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Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

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