LANGHOLM
Flood Protection Scheme

Flood Management Options Report

IBE1511 Langholm FPS
Flood Management Options Report
F02

rps MAKING COMPLEX EASY

Dumfries & Galloway COUNCIL

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1 INTRODUCTION

1.1 Background

The town of Langholm is located in the Dumfries and Galloway region of Southern Scotland. The main watercourse influencing Langholm is the River Esk. The town is also influenced by the smaller tributary rivers, the Ewes Water and the Wauchope Water which join with the River Esk at Langholm. All three watercourses pass through mainly rural areas before entering the town of Langholm. Within Langholm, the watercourses pass through a mixture of residential and commercial properties.

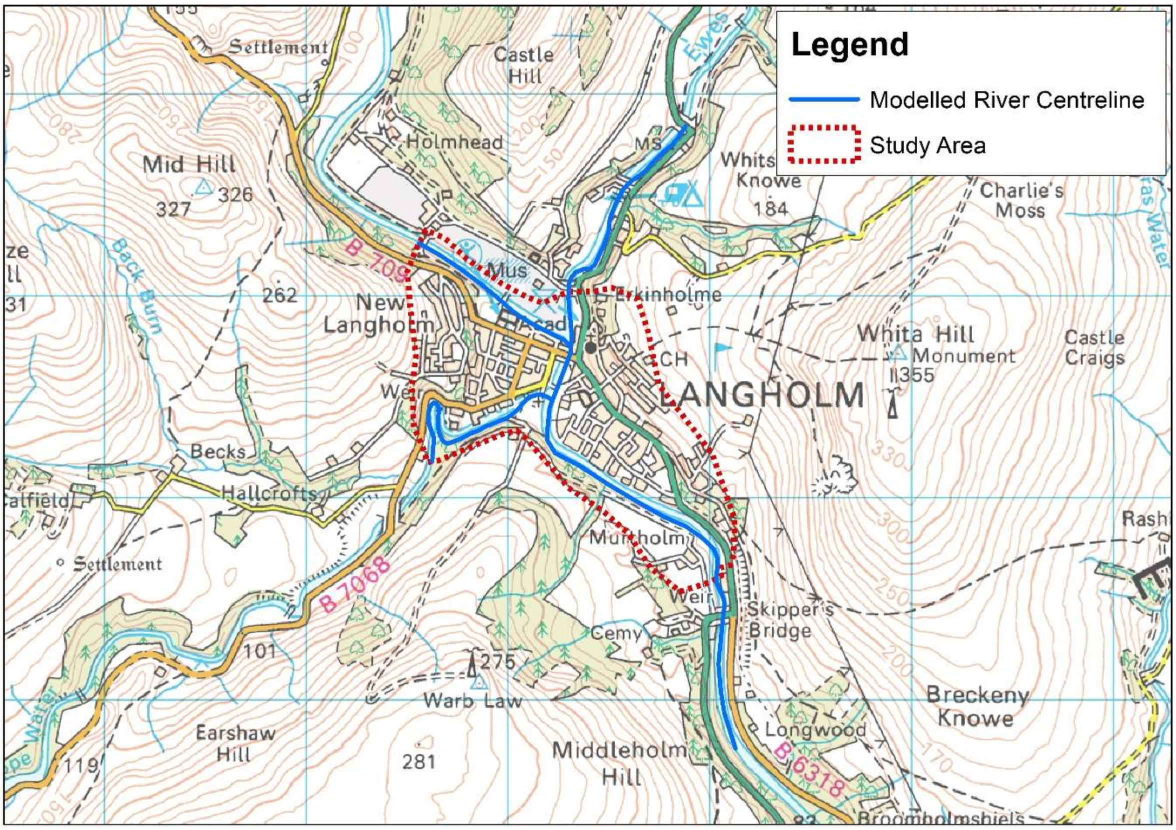

Figure 1.1: Langholm Study Area

1.2 Aims & Scope

Dumfries and Galloway Council commissioned RPS to carry out an outline design for a potential Langholm Flood Protection Scheme. As part of the outline design process, this study was carried out to identify the optimum solution for flood defence in the area.

The aims of the study are summarised below:

- Identification of possible sustainable flood mitigation actions to protect existing properties and key infrastructure to a 0.5% Annual Exceedance Probability (AEP) (1 in 200 year) flood event.
- To conduct a Baseline Natural Flood Management (NFM) assessment to identify, potential opportunities for NFM in the catchments influencing the area.
- Assessment of flood mitigation options and selection of preferred flood mitigation option.
- Conceptual design of preferred flood mitigation options.
- Outline costing of preferred flood mitigation options.
- Outline cost-benefit analysis of preferred flood mitigation options
- Reporting of findings.

The aim of this report is to outline sustainable flood mitigation measures identified to protect existing properties and infrastructure. It is also to determine the technical, economic, social and environmental feasibility of the preferred options. Throughout this study, flood mitigation options are based on a 0.5% AEP (1 in 200 year) flood event plus freeboard, (500mm for walls, 600mm for embankments).

Note: Freeboard is additional height added on to the design wall height to allow for uncertainties in the design process. The initial freeboard heights discussed above are used at this feasibility stage of the scheme but should be re-assessed at the outline design stage in line with Environment Agency (EA) Guidance 'Delivering Benefits through Evidence – Accounting for residual uncertainty: updating the freeboard guide'.

2 STAGE ONE: DEFINING THE PURPOSE

In defining the purpose of this study, a clear description is required of the problems faced including an understanding of the existing flood risk, how this risk will change over time and if there are any major constraints that may affect the choice of a solution.

Langholm has experienced a number of flood events in recent years. The most recent notable flood event for which records exist occurred in December 2015 (Storm Frank). During this event, the River Esk burst its banks and homes on George Street were evacuated by the Police. Other notable events include, August 2012 where a number of small watercourses in Langholm flooded, affecting private properties and the A7 Trunk Road, November 2009 when record rainfall prompted rivers to overflow in the area and a number of roads were closed, 1990 where the A7 and local businesses were flooded and August 1964 where surface water flooding caused the A7 in Langholm to be closed. Unfortunately for the mentioned events, very little data was collected. This meant that these events were not able to be relied upon for model calibration. Photographs of flooding were used to carry out visual checks of flood extents and this allowed some model validation to be carried out. Details of this calibration can be found in the Langholm Hydraulic Analysis Report.

The hydraulic model simulated the 0.5% AEP (1 in 200 year) flood event for the River Esk, Ewes Water and Wauchope Water. The flood extents produced from the model are included in Appendix A. The following flooding mechanisms can be observed from the model:

- Flows greater than channel capacity on the Ewes Water cause overtopping and widespread inundation along the right bank of the river, north of Langholm town centre. This includes Greenhead, Langholm Mill and the grounds of Langholm Castle. On the left bank of the Ewes Water overtopping causes flooding to the Kiln Green area.
- Flows greater than channel capacity in the River Esk cause flooding to Mary Street, Montague Street, Esk Place, Frances Street, Buccleuch Place, William Street, Elizabeth Street, Thomas Telford Road, George Street, Charles Street and John Street.
- Flows greater than channel capacity within the Wauchope Water result in overtopping and inundation along the length of Caroline Street.
- Flows greater than channel capacity at the confluence of the Wauchope Water and River Esk cause overtopping of both the bank and stonewalls surround Langholm Parish Church. This results in flooding of both the church building and grounds.
- Flows greater than channel capacity in the River Esk to the south of Langholm flow across the Waterside area footpath and cause inundation to Lairds Entry, Rosevale Gardens, Maxwell Road, West Street, Ardill Road, Waverley Road and Glenesk Road.
- Two weirs were identified in Langholm, one on the Wauchope Water and the other between the footbridge and the Thomas Telford Bridge. During extreme flood events, both of these weirs are submerged and therefore have no impact on flooding.

An assessment of the flood risk was carried out for the study area. Table 2.1 details receptors at risk during a 0.5% AEP (1 in 200 year) flood event and also any constraints to potential flood management solutions. The receptors are presented in the figures found in Appendix A.

Table 2.1: 0.5% AEP (1 in 200 year) Flood Event Receptors

Receptor/Asset Affected	Impact of Flooding	Constraints to Solution
Residential Properties	188 residential properties at risk. The total present value damage was calculated at £5,099,093	-
Commercial Properties	74 commercial properties at risk. The total present value damage was calculated at £9,188,761	-
A7 - Townhead Road	Traffic Disruption	-
Mary Street		
George Street		
High Street		
Glenesk Road		
Caroline Street		
Thomas Telford Road		
Elizabeth Street		
Listed Buildings:	-	These buildings cannot be altered due their historical or architectural significance.
Langholm Church of Scotland		
Thomas Telford Bridge		
Ewes Bridge		
Edinburgh Woollen Mill		
Thomas Hope Hospital		
Buccleuch Estate Building		
Langholm Community Centre		
Conservation Zone: Langholm	-	Minimise the detrimental impacts to this zone during construction. Ensure than no lasting negative impact on the environment is brought about by the flood defences.
Langholm CSO	Disruption to service	-
Langholm WWTW		
SGN Gas Station		
Public Amenity Area (to SW of the Church of Scotland.)	Lasting Damage to Amenities	Incorporate the Community Council proposed park in the area into the scheme.

2.1 Review of Damage Profile

In order to select an appropriate Standard(s) of Protection (SoP) a damage profile curve was extracted from the Damage Assessment (for method see Appendix B) and is presented in the figure below. The damage profile can be used to provide an indication of relative benefit. As the damage increases with the flood events so will the potential benefit from any scheme that would provide protection to that flood event standard. Where the damage increase from one flood event to the next is large there is potential that the benefit would also be large therefore providing a cost beneficial solution. This assumes that the cost of the scheme would increase more uniformly from one flood event to the next.

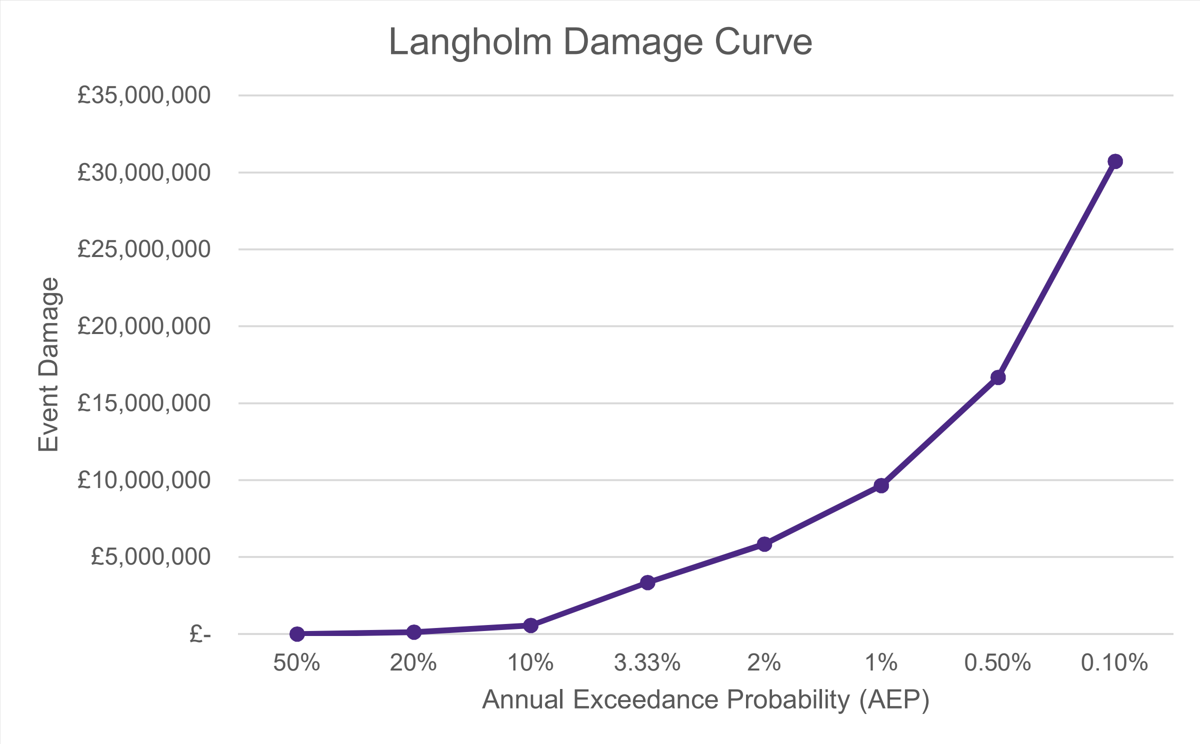

Figure 2.1: Damage Curve

The damage profile shows a relatively uniform increase in damages from the 10% AEP to the 1% AEP flood events. The increase in damage becomes larger when considering the 0.5% AEP (1 in 200 year) event and even larger during the 0.1%AEP event. From the damage profile it is therefore appropriate to consider the 0.5% AEP (1 in 200 year) flood event as the potential SoP. Consideration of the 0.1% flood extent is outwith the scope of this assessment.

2.2 Set Objectives

In addition to the aims set out in Section 1.2 of this report, objectives from the Flood Risk Management Plan and specified objectives have been set based on the risks and constraints identified.

2.2.1 Objectives in the Solway Flood Risk Management Plan for the River Esk Catchment (PVA 14/04)

- Reduce the economic damages and risk to people in Langholm from flooding.
- To avoid an overall increase in flood risk.
- To reduce flood risk.

- For organisations such as Scottish Water, energy companies and Historic Environment Scotland to actively maintain and manage their own assets, including the risk of flooding. (These actions are not detailed further in the Flood Risk Management Strategies.)

2.2.2 Specific Objectives

- The flood mitigation option should provide a 0.5% AEP (1 in 200 year) Standard of Protection (SoP) to all residential and commercial properties in the study area
- Reduce flood risk to roads
- Improve overall flood resilience of the area
- Minimise the negative impacts of providing defence to Langholm
- Identify the most sustainable solution, taking into account the cost-benefit ratio of the option as well as the social and environmental impacts

3 STAGE TWO: DEVELOP, DESCRIBE AND VALUE

3.1 Identify Long List of Actions

An assessment was carried out to identify a long list of flood management actions. This list was based on the objectives established in the previous chapter. Actions were considered that; could partially or completely address the flood risk; that could be implemented at various scales (catchment level to property level); and that could be combined. The assessment included actions that could deliver sustainable flood risk management and that could help manage flood risk in the future. Actions that deliver wider benefits such as improved places to live and improved environment and biodiversity were considered along with actions that could improve existing actions such as maintenance regimes.

Using SEPA's standard list of actions (see Appendix D for the full list), the following actions have been identified for Langholm.

Table 3.1: Long List of Actions

Action	Action Type	Description
Relocation	Avoid	While large scale relocation of properties would be considered an unsustainable approach, there may be specific properties or groups of properties that may be suitable for relocation out of flood risk areas. Other receptors such as recreational areas or transport assets would also be considered for relocation.
Storage	Reduce/Protect (Engineering)	Storage areas may be available within the study catchments which could reduce the peak flow and therefore the flood risk.
Conveyance – Channel Re-profiling	Reduce/Protect (Engineering)	Lack of channel capacity has been identified as a contributing factor to flood risk. Improvement of channel conveyance could reduce this flood risk.
Conveyance – Flow Diversion	Reduce/Protect (Engineering)	Flow diversion can be an effected method of removing large volumes of flood water away from sensitive areas.
Sediment Reduction	Reduce/Protect (Engineering)	Removal of built up sediment, can increase channel capacity.
Direct Defences	Reduce/Protect (Engineering)	Flood walls and embankments could be used throughout the study area to reduce flood risk.
Property Level Protection (PLP)	Reduce/Prepare	While PLP might not be able to provide the design SoP it can reduce the flood risk to suitable properties.
Flood Forecasting & Warning	Reduce/Prepare	Flood forecasting and warning systems enable property owners and emergency services to prepare for flooding therefore reducing the impact and damage incurred.
Self Help	Reduce/Prepare	Informing the public or forming community flood action groups who live, work or use a flood risk area on the risks of flooding and how to prepare for flooding. This can minimise the impact of flooding and therefore help to reduce flood risk.
Emergency Plans and traffic management	Reduce/Prepare	Development of emergency flood response procedures can reduce the impact when flooding occurs. Traffic management could reduce the impact to important social receptors.

As part of this report, a Baseline NFM assessment was also carried out. This can be found in Section 3.3.

3.2 Screening the Long List of Actions

The long list of actions was screened in order to remove actions which are not feasible. Actions which are deemed technically inappropriate, technically impractical or have insurmountable constraints were screened out.

Table 3.2 below summarises the results of the screening process set out in this report. The text that follows provides details of the screening assessment.

Table 3.2: Summary of results of screening List of Actions

Action	Comment	Feasible
Relocation	This action is dependent on the receptors at risk and the appropriateness of relocating them.	✓
Storage	This action is dependent on the natural topography of the river catchments and the volume of water which would be required to be stored in order to adequately reduce the risk of flooding.	×
Conveyance - Re-profiling	This action is dependent on channel capacity along the watercourses within the study area.	×
Conveyance - Flow Diversion	This action is dependent on space being available in which to position flow diversion and that the diversion has positive impacts on flood levels.	✓
Sediment Reduction	This action is dependent on there being areas of deposited sediment which could be removed to have a positive reduction on flood extents.	×
Direct Defences	This action depends on the locations where out of bank flooding are occurring and if there is enough space available to add hard defences.	✓
Property Level Protection	This action's feasibility depends on the depth of flooding to the property and is particularly suited to isolated properties.	✓
Flood Forecasting & Warning	SEPA launched a flood warning system in the study area in March 2017.	✓
Self Help	This action's feasibility is dependent on the knowledge that homeowners and business owners have on how best to protect their properties against flood damage.	✓
Emergency Plans and Traffic Management	This action's feasibility is dependent on the awareness the public has regarding what procedures to follow in a flood emergency.	✓

3.2.1 Relocation

When considering which receptors may be suitable for relocation, the social, technical and economic factors were considered. Such factors included; would removing the receptor have a detrimental impact on the local community; are there other suitable areas zoned to accommodate the relocation; and would the cost be disproportionate to the present day damage from flooding.

When assessing which properties may be suitable for relocation, the market value of the property was considered against the damage which the property may occur through flooding. Properties were only considered suitable for relocation if the damage which they may incur through flooding was greater than their market value. In addition to this properties were considered suitable for relocation if they are single isolated properties or isolated groups of properties.

The initial screening process concluded that no properties within the study area were suitable for relocation.

3.2.2 Storage

A review was carried out to identify if any areas suitable for either online or offline storage exist naturally in the topography around Langholm. In general the topography surrounding Langholm is relatively steep. A check was carried out to ascertain if any suitable storage locations in the catchments influencing Langholm could be found. This process was carried out by analysing the digital terrain model (DTM) of the area and identifying areas of land which have the ability to store water, whilst only requiring a short length of dam structure.

This process found five potential areas which could be suitable for online storage. The five areas are shown in Figure 3.1. A visual study was also carried out of the upper areas of the catchment using the DTM, to ascertain if there were any areas suitable for offline storage. This study aimed to identify any areas of land which with little modification could retain water during times of flooding. Due to the steeply sloping, well defined valleys within the Langholm catchment, no such areas were identified.

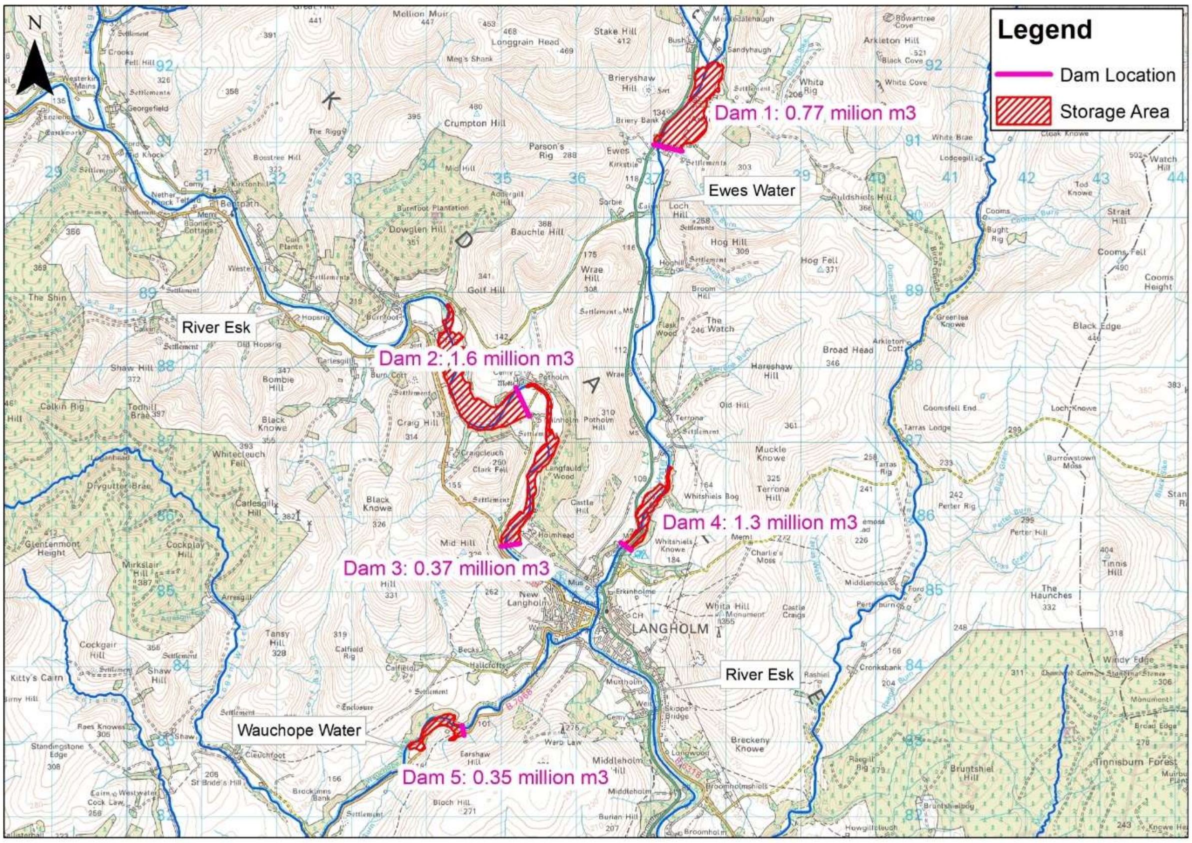

Figure 3.1: Potential Online Storage Locations

The storage capacity of these five storage areas were calculated using the ArcMap Spatial Analysis tool. The combined storage capacity was compared with the flood event hydrographs to give an indication of effectiveness. It was found that a combined storage volume of 4.39million m^3 could potentially be achieved leaving a residual flow through Langholm equivalent to a 2% AEP (1 in 50 year) flood event.

Table 3.3: Potential Storage Areas

Dam No.	Capacity (millions m^3)	Approximate Cost (£millions)
1	1.3	7.2
2	1.6	7.7
3	0.77	4.3
4	0.37	3.1
5	0.35	2.4
Total	4.39	24.7

It is anticipated that five storage dams would have high costs and may not be cost beneficial. A high level costing exercise was therefore carried out and is summarised in Table 3.3. The total cost was estimated to be £24.7m. In addition to this cost additional defences would be required in Langholm. With an equivalent flow a 2% AEP (1 in 50 year) flood event a length of 1600m of river bank would still overtop requiring additional defence and cost. Given that the estimated cost is larger than the present value damage of properties, see Table 2.1, this action is not economically viable and was not considered any further.

3.2.3 Conveyance - Channel Profiling

Additional flood conveyance channels can be added to an area to quickly move flood water away from areas where flooding occurs, as well as potentially adding to the overall channel capacity.

3.2.3.1 2 Stage Channel

Initial screening identified the potential for the addition of a 2 stage channel profile to two areas of Langholm. For an area to be considered as suitable for additional conveyance channels, a number of topographic and flooding mechanism factors need to be considered. Conveyance channels require a relatively flat area in the adjacent floodplain which can be re-profiled at relatively small expense.

Due to areas of steeply sloping land adjacent to the riverbank, only the areas identified in Figure 3.2 were suitable for re-profiling.

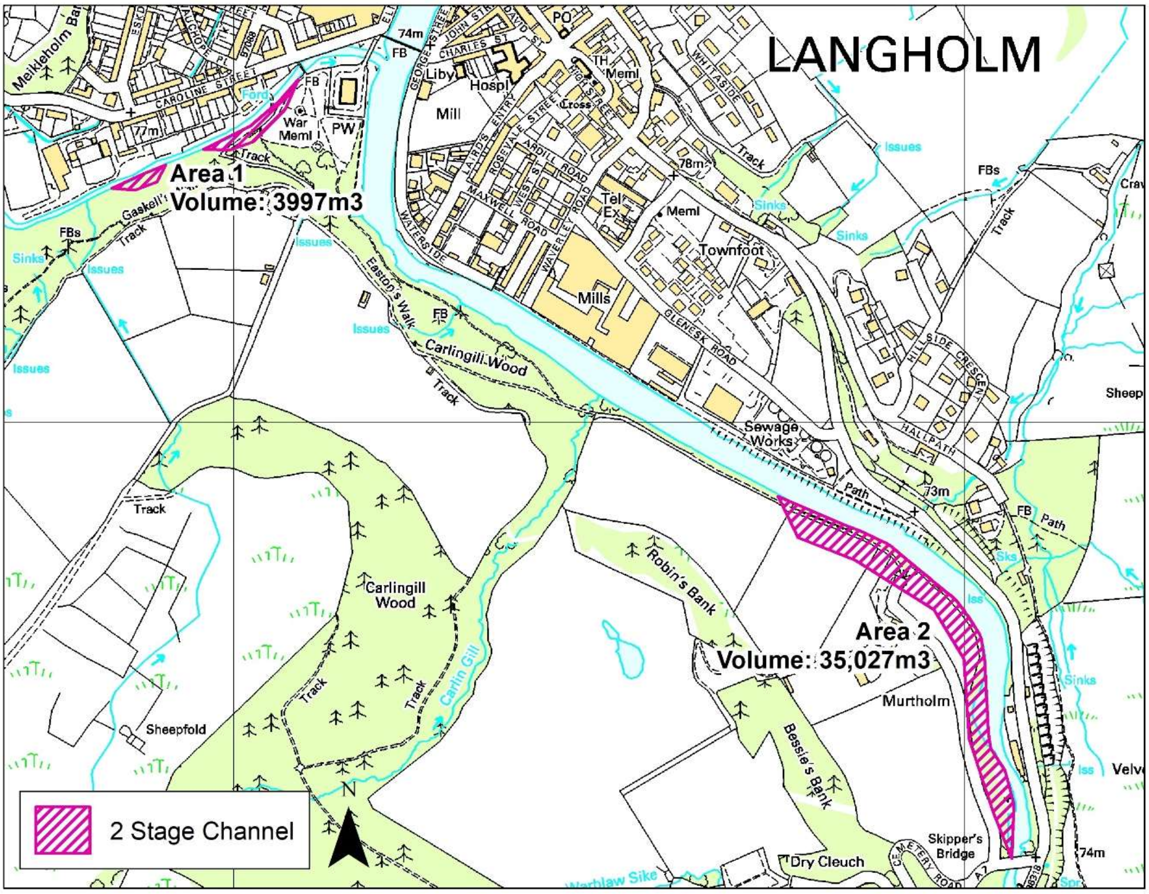

Figure 3.2: Potential 2 Stage Channel Locations

To quantify the effect that the addition of the 2 stage channel would have had on flood levels in Langholm, average flood levels were extracted from three locations. These locations are shown in Figure 3.3. The three locations identified were chosen as they represented the most significant areas where direct defence are required in Langholm. If a reduction in required defence heights in these areas could be achieved by increased conveyance, then there may be significant economic and social benefits.

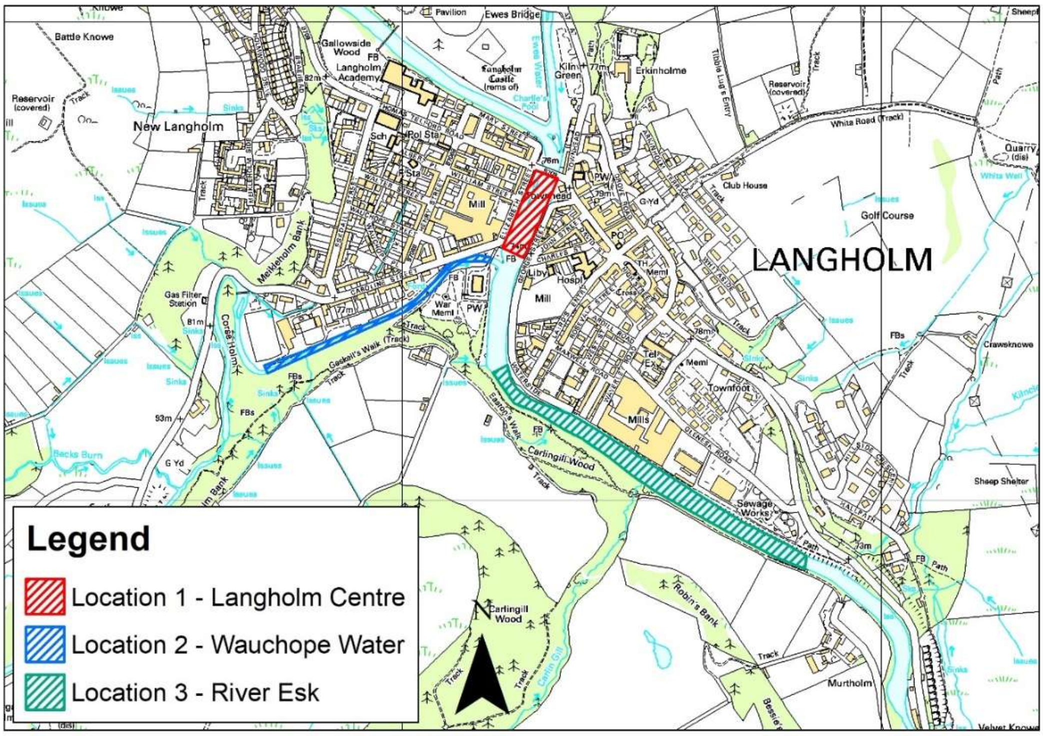

Figure 3.3: Level Sampling Locations

The addition of 2 stage channels in these two areas was modelled to quantify the effect it may have. The results of this analysis are shown in Table 3.4.

Table 3.4: Level Comparison - 2 Stage Channel

Location:	Average Difference (m):
1	-0.04
2	-0.12
3	-0.12

The data in Table 3.4 shows that the addition of 2 stage channels would bring about a reduction in water levels in the identified locations. However, to create this effect would require the removal of vast amounts of material from private land areas. This would be neither economically or environmentally acceptable. Due to this, 2 stage channels were not considered as a feasible option.

3.2.4 Conveyance - Flow Diversion Channels

The addition of extra conveyance channels in an area may increase the overall channel capacity. This increase can reduce the amount of out of channel flooding. The location shown in Figure 3.4 below was identified as being potentially suitable for flow diversion measures.

3.2.4.1 Bypass Channel

It was identified that a bypass channel could be inserted in the location shown in Figure 3.4. This bypass channel would remain dry in normal flow conditions and would only carry water when a flood event of 10% AEP or higher was experienced.

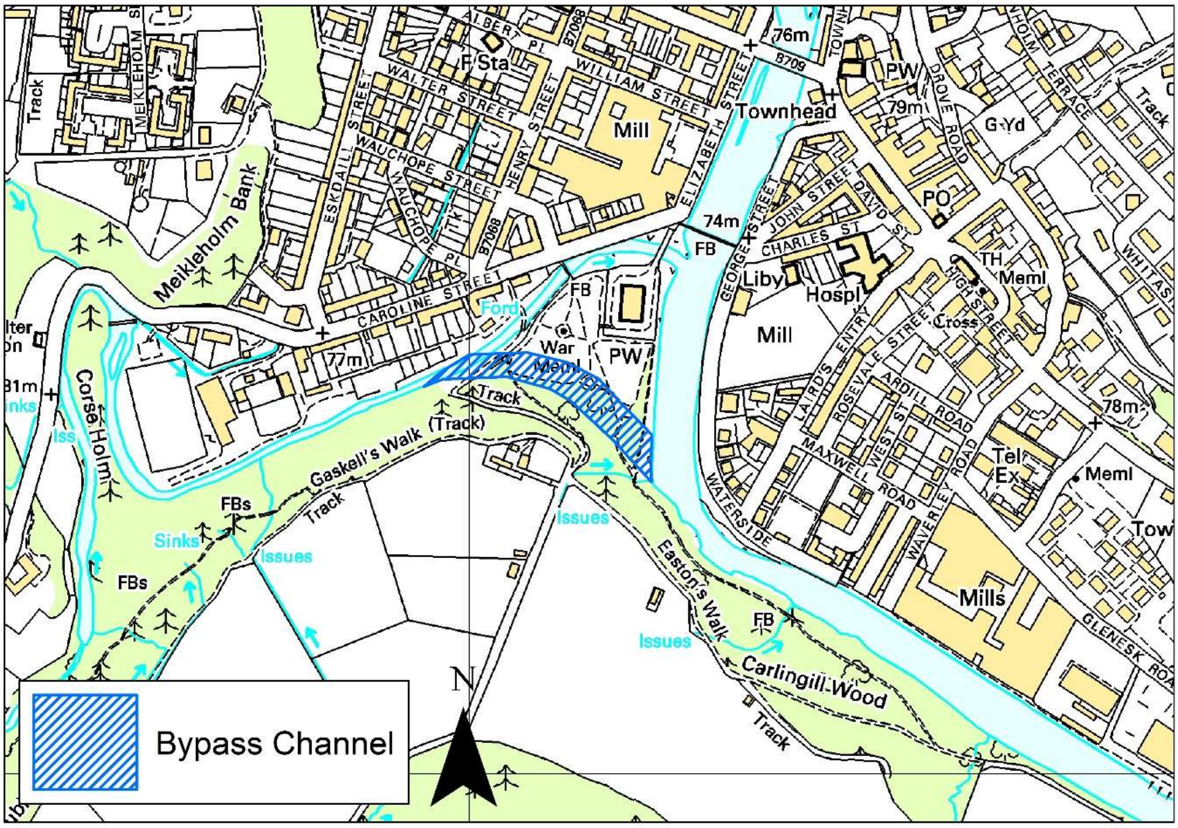

Figure 3.4: Bypass Channel

Table 3.5 below provides a summary of the average increase/decrease brought about by the addition of the wide church bypass in the locations shown in Figure 3.4 during a 0.5% AEP (1 in 200 year) event.

Table 3.5: Level Comparison – Bypass Channel

Location:	Average Difference (m):
1	-0.16
2	-0.10
3	+0.01

The results in Table 3.5 show that the addition of the bypass channel in Langholm reduce water levels in both the Wauchope Water and the River Esk as it flows in the centre of Langholm. It can also be seen that in location 3, a small increase in water level occurs. While this action will not reduce the water levels enough to be considered a standalone action it would contribute to reducing the remaining defences required. Therefore it is considered feasible in combination with other actions.

3.2.4.2 Realigning the Channel

Realigning a river channel can bring about a reduction in flooding by increasing the efficiency by which water moves through the area. When considering the potential suitability of an area for channel re-routing, the effect it has on water levels both upstream and downstream of the location must be taken into consideration.

Realigning the Wauchope Water to the arrangement shown in Figure 3.5 below was considered as an option.

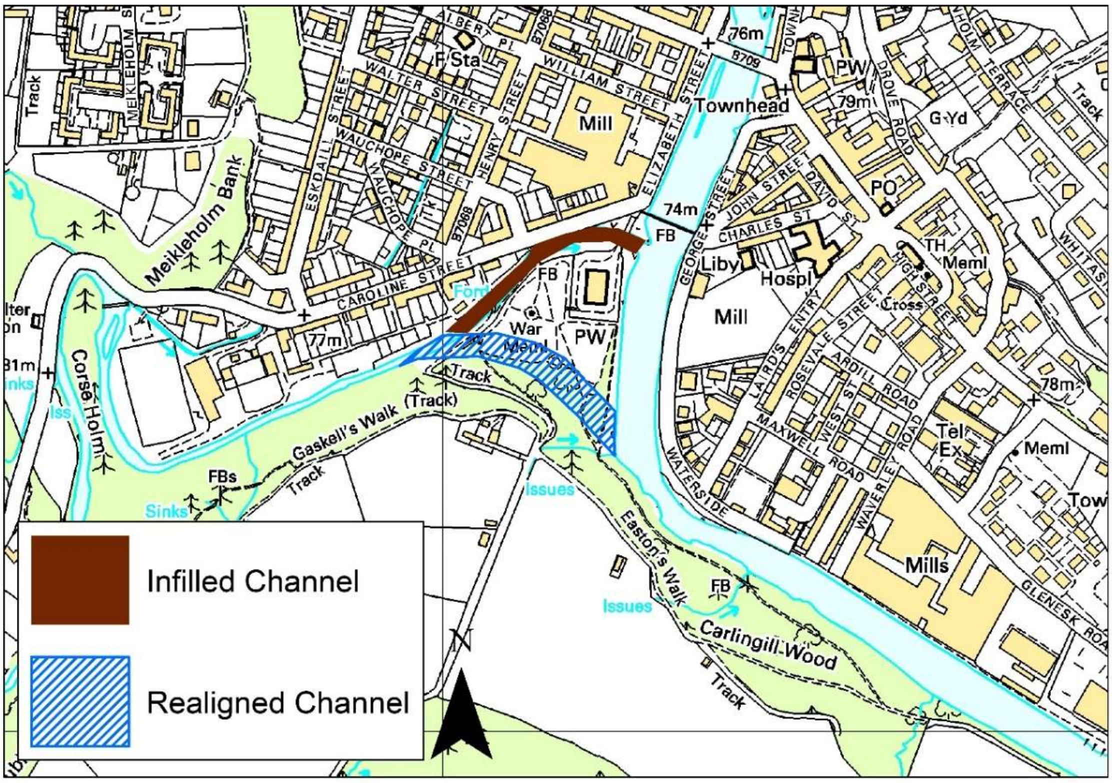

Figure 3.5: Proposed Realignment Location

To quantify the effect that realigning the channel would have on water levels, the three sampling locations shown in Figure 3.3 were again used to compare water levels in a 0.5% AEP (1 in 200 year) design event. Table 3.6 below shows the result of this comparison.

Table 3.6: Level Comparison – Realignment

Location:	Average Difference (m):
1	-0.19
2	-0.10
3	+0.02

The results in Table 3.6 show that the addition of the bypass channel reduces water levels in both the Wauchope Water and the River Esk as it flows in the centre of Langholm. It can also be seen that in location 3, a small increase in water level occurs. While this action will not reduce the water levels enough to be considered a standalone action it would contribute to reducing the remaining defences required. Therefore it is considered feasible in combination with other actions.

3.2.5 Conveyance - Sediment Management

An increase in channel capacity can potentially be brought about via the removal of sediment from the river bed. Sediment carried downstream in a river is deposited when the water flow slows down enough for the river to no longer have the energy to hold sediment particles in suspension. This occurs in areas where the river bed is relatively flat, at river bends and where there are obstructions in the river channel which hold up the flow of water, e.g. weirs and bridge abutments.

The build-up of this sediment can potentially reduce channel capacity in normal conditions. This sediment build up can be removed from identified areas via dredging and the river bed can be re-profiled in such a way that it promotes good flow through an area, reducing potential deposition of sediment.

On first inspection, the River Esk in particular looked to be suitable for sediment management. cbec, a company specialising in fresh water restoration, was instructed to carry out a study of the area. cbec analysed the impact of removing sediment from the River Esk on the flooding in the area. The study identified the location shown in Figure 3.6 below, as being an area where the removal of sediment may have a beneficial effect on flood extents.

cbec used a hydromorphological model to simulate the removal of this gravel bank from Langholm. They then compared modelled flood heights pre and post gravel removal to analyse whether the sediment removal had a significant impact on flood levels. The results showed that the removal of sediment had a small positive effect on water levels (approximately: -0.2m), over a very localised reach of the River Esk.

No other suitable areas for sediment reduction were found and due to this, and the findings of cbec report, it was concluded that sediment removal as a flood reduction action was not feasible.

Sediment management is also discussed in the NFM section of this report, Section 3.3.

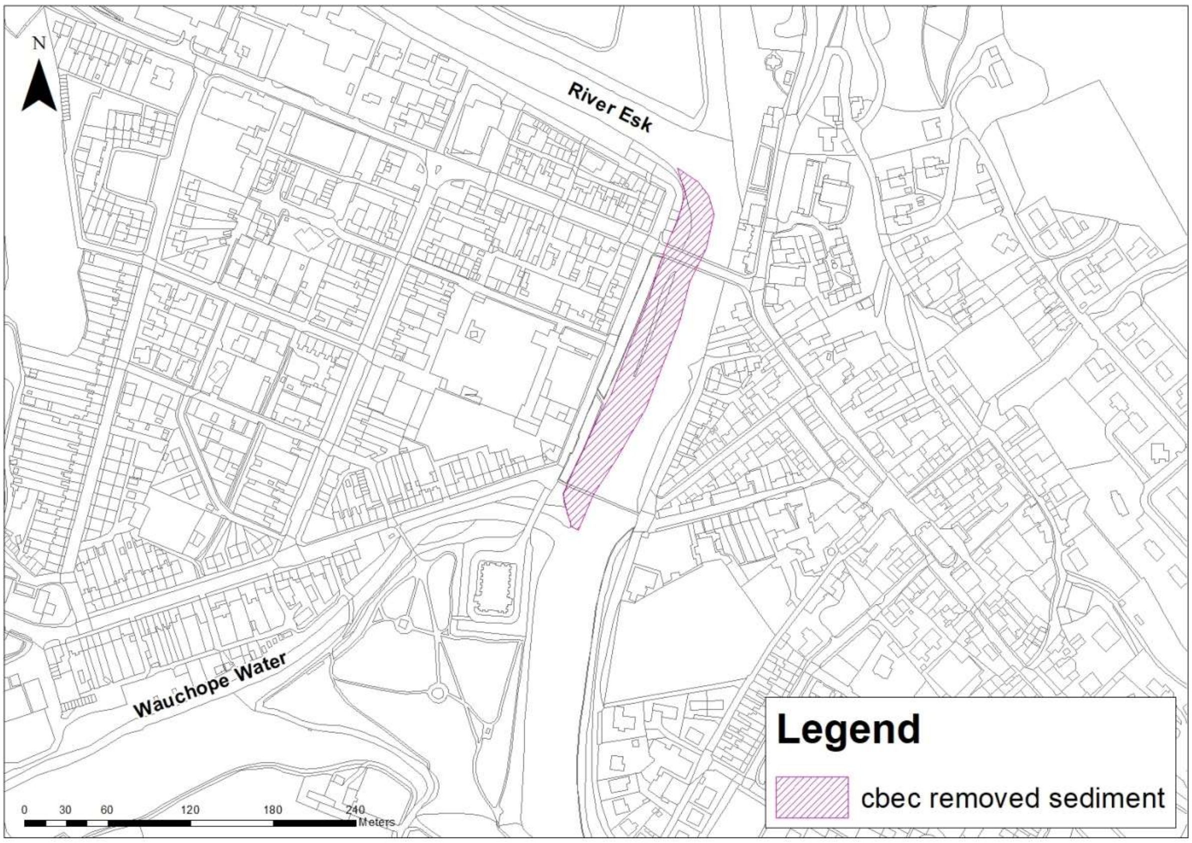

Figure 3.6: Area of Sediment Removed

3.2.6 Direct Defences

A review was carried out to ascertain where hard defences would be required to protect properties at risk during a 0.5% AEP (1 in 200 year) flood event. To determine the effectiveness of the hard defences, a hydraulic model was constructed to simulate the method of protection. The proposed location of hard defences in Langholm is shown in Figure 3.7 to Figure 3.9. Space in Langholm is limited, therefore the line of the proposed defences must be close to the watercourses. Direct defences are considered a feasible action for the study area.

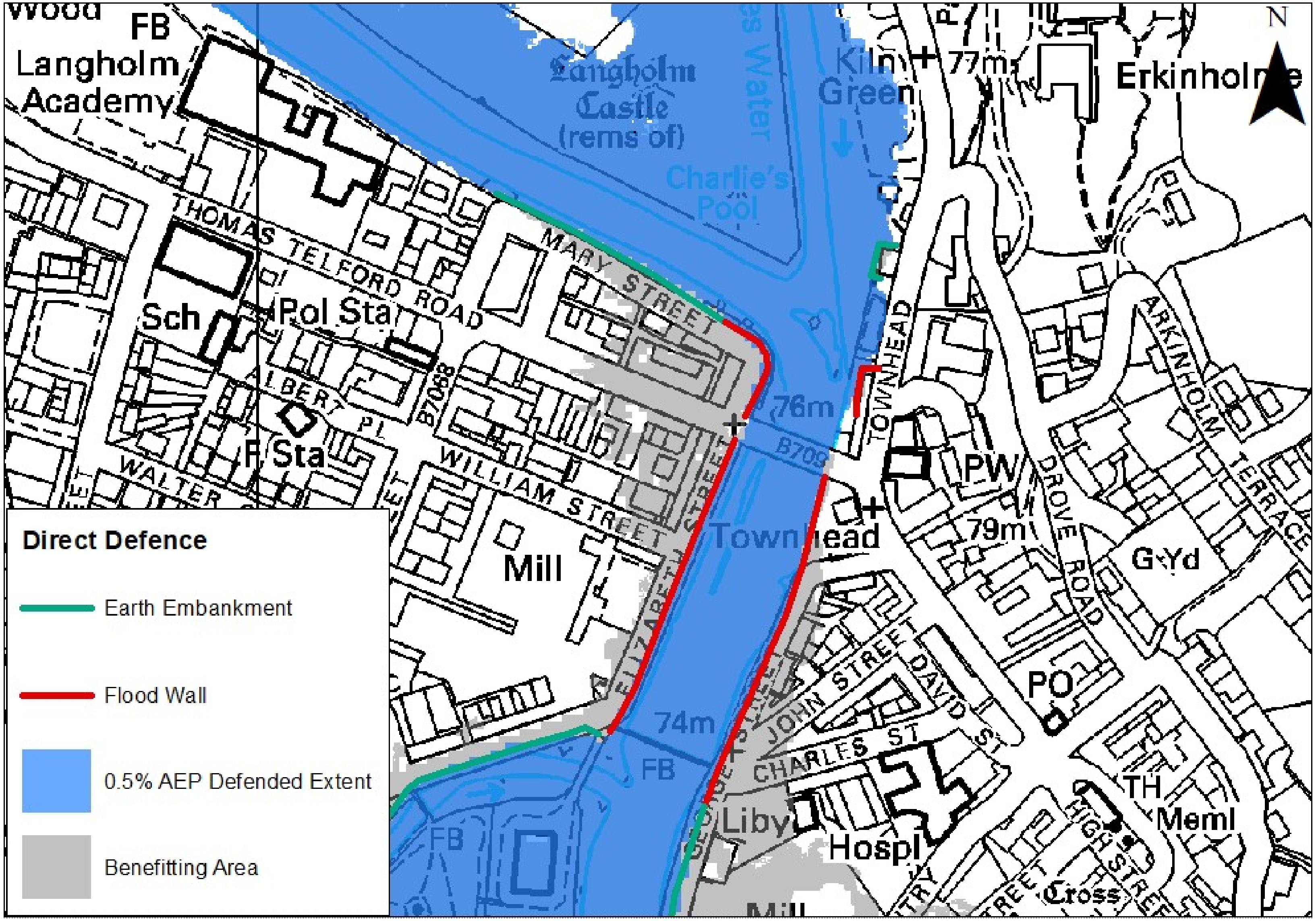

Figure 3.7: Direct Defence Locations 1

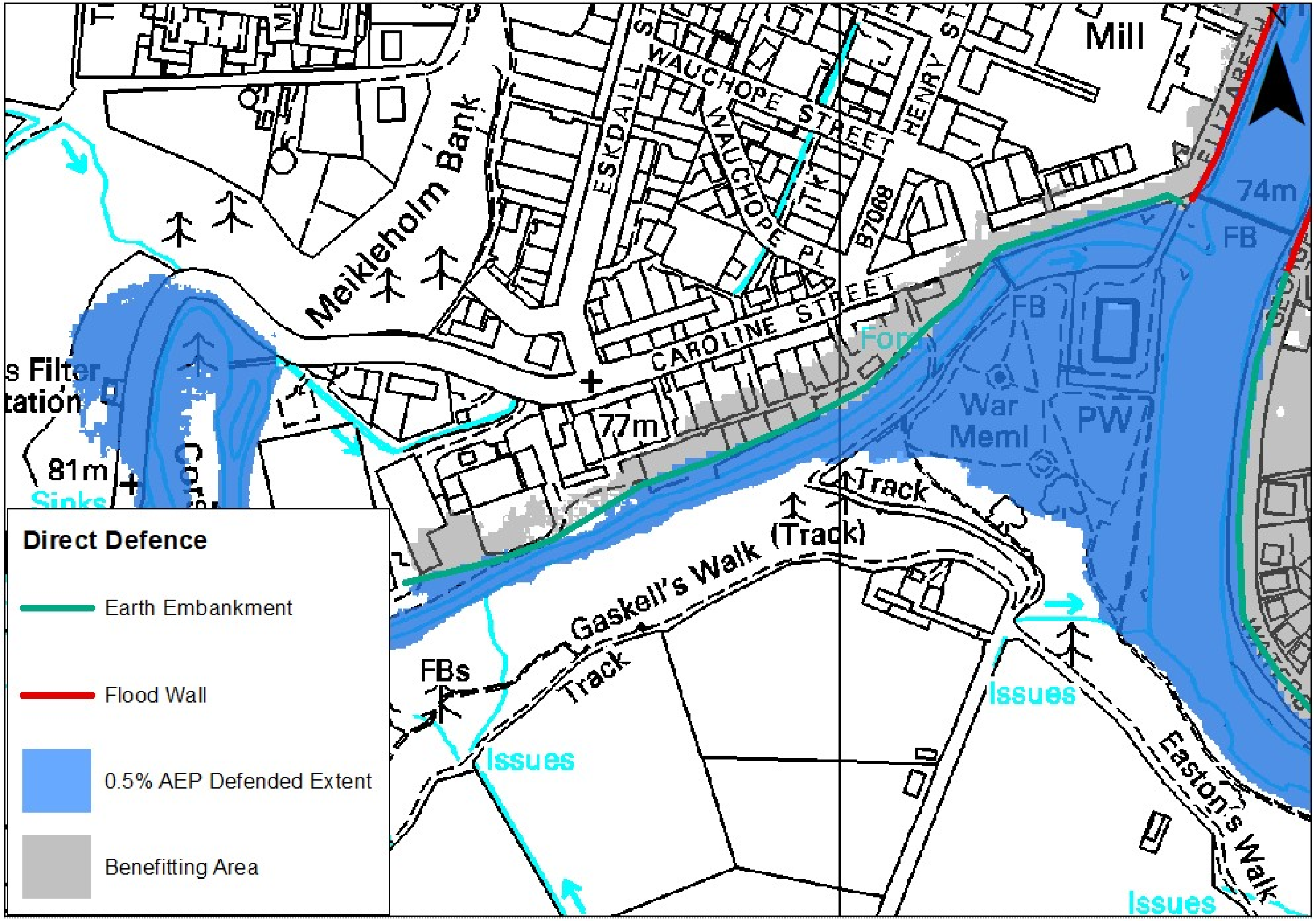

Figure 3.8: Direct Defence Location 2

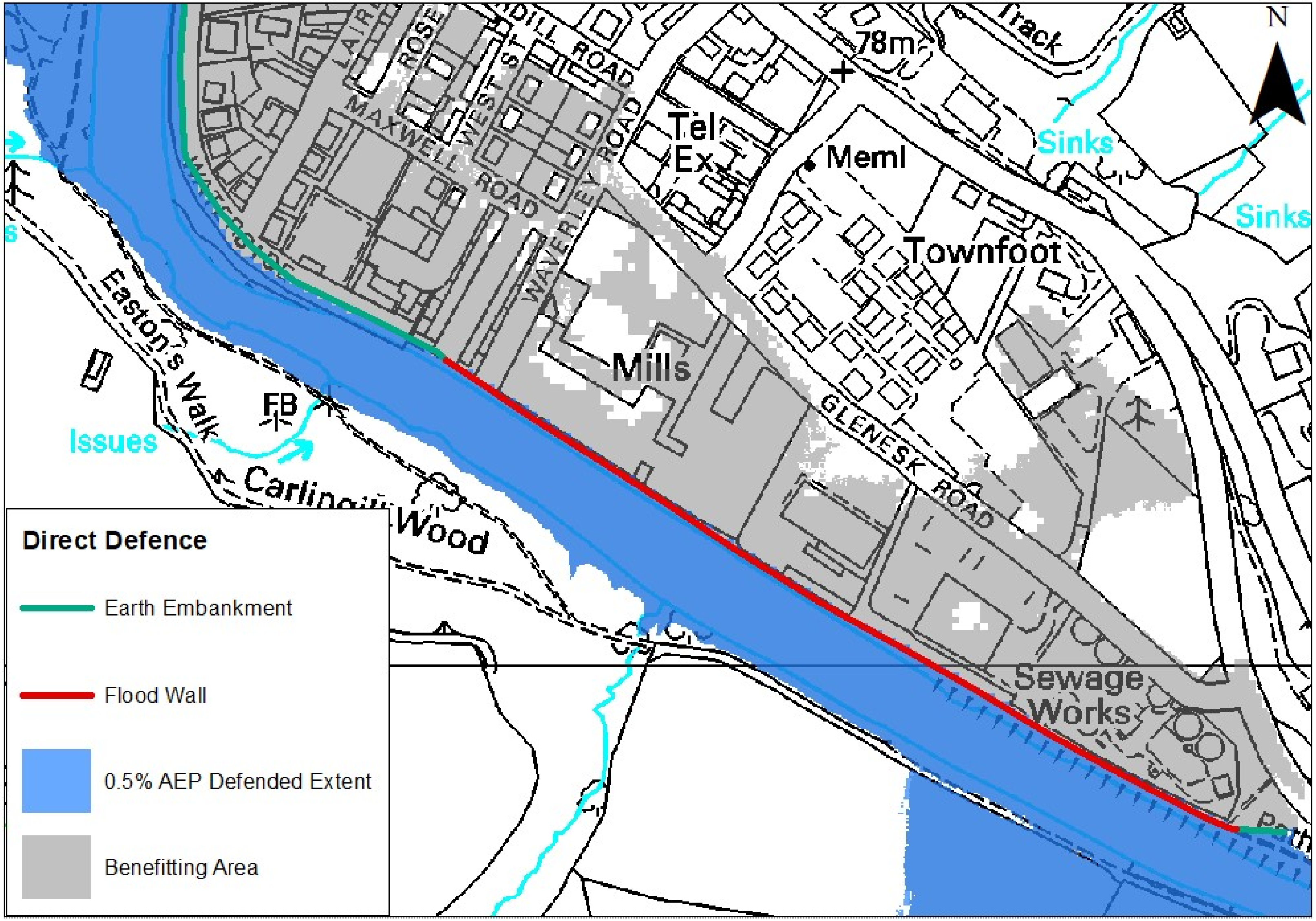

Figure 3.9: Direct Defence Location 3

3.2.7 Property Level Protection

Property Level Protection (PLP) could be provided to all at risk properties in Langholm. This would consist of ways to prevent water entering a property such as flood gates and air vent covers. PLP would provide protection up to a depth of 0.6m, beyond which water would be allowed to spill over the defence and into the buildings in order to limit the hydraulic pressure exerted on a building's walls and ensure its structural integrity. Some properties would only therefore be protected during lower flood event return periods. Additional uncertainty is inherent with PLP in that it relies on user intervention to install the defences when required. This action while not providing the full SoP would be effective in reducing the flood risk and was therefore considered feasible.

3.2.8 Flood Forecast and Warning

The key benefits of a flood warning scheme are:

- Individuals and business are able to move valuable items away from a flood risk zone. Flood warning would increase the time available to move property including cars, furniture, equipment, items of emotional value etc.
- Emergency services would be able to have adequate resources on stand-by and mobilise these in a timely manner.
- Temporary flood protection measures (including flood gates, sand bags, pumping equipment, etc.) could be prepared and implemented depending on the expected magnitude and timing of a flood. This could be relevant both to Dumfries & Galloway Council and emergency responders (resourcing of staff and equipment) as well as individuals (property level protection measures).
- Flood forecasting and warning would provide detailed information to inform road closures and evacuations to minimise risks to human health.

A flood warning system instigated by SEPA has been in operation in Langholm since March 2017. This scheme has the potential to benefit 751 properties in Langholm from advance notice of flooding, giving communities and businesses time to take action to reduce the damage and disruption that flooding can cause.

The flood warning system currently in operation will be beneficial regardless of the flood defence method chosen.

3.2.9 Self Help

A public awareness campaign would be useful in the Langholm area to alert residents and business owners to the types and sources of flooding in their area. It was established that currently the vast majority of residents in Langholm are unaware of the potential risk their town is at from flooding. This would allow individuals to take informed actions to help prevent their property from flooding.

3.2.10 Emergency Plans and Traffic Management

The preparation of emergency response plans would be beneficial in the event of a severe flood event so as to help residents and business owners affected safely evacuate and navigate the flooded areas.

Identifying alternative routes could minimise traffic disruption and way of life.

It was identified that in a flood event, an alternative route would be required to allow traffic to get across the River Esk from east to west and vice versa. Due to the rural location of Langholm, the lack of road network and the limited crossings of the River Esk in the area, providing an emergency route during flooding using suitable roads was difficult. Due to uncertainties in whether bridges outside the model extent will be flooded during events, two possible emergency routes have been included in this report.

The two possible routes are shown in Figure 3.10 & Figure 3.11.

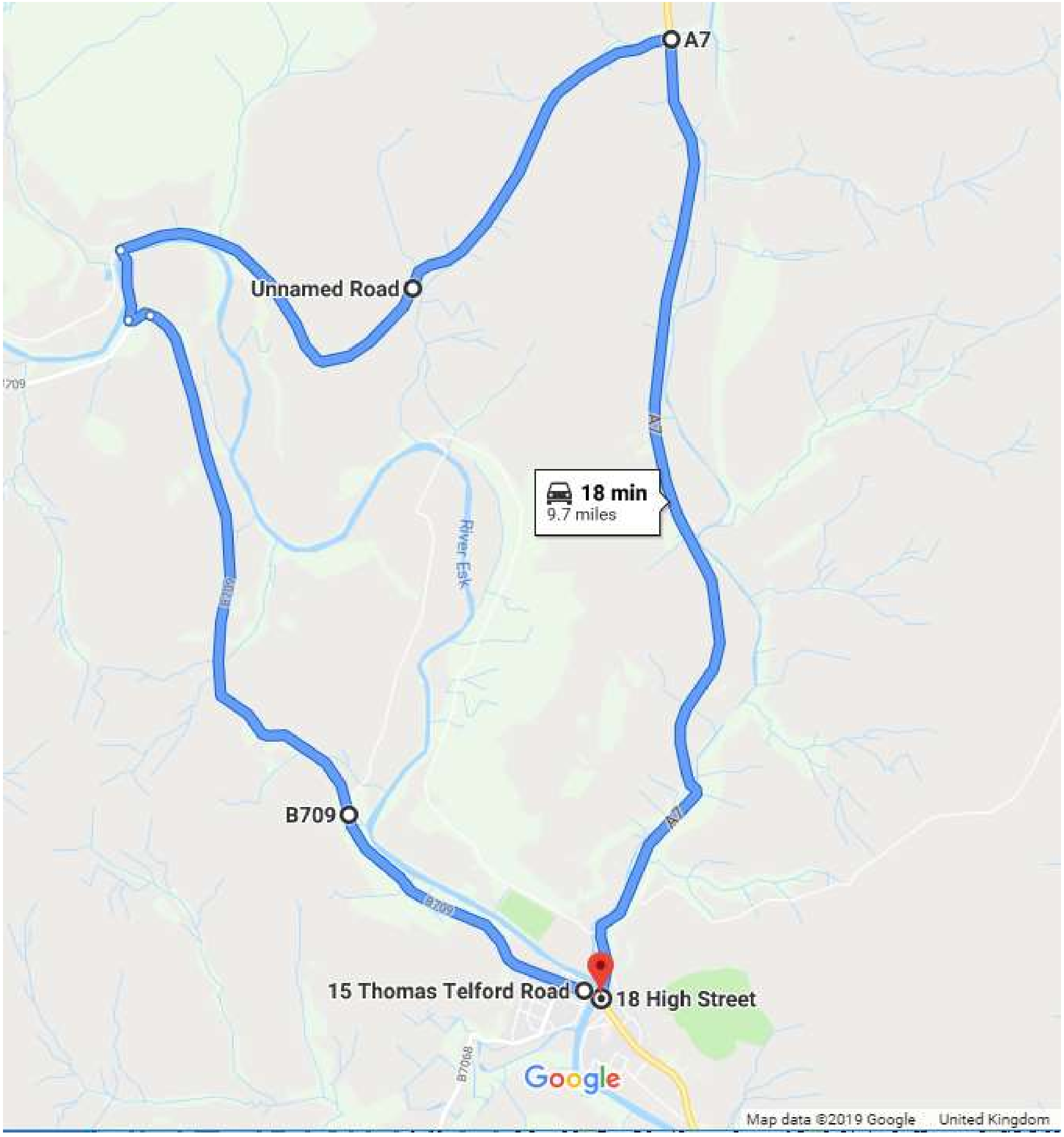

Figure 3.10: Emergency Route 1

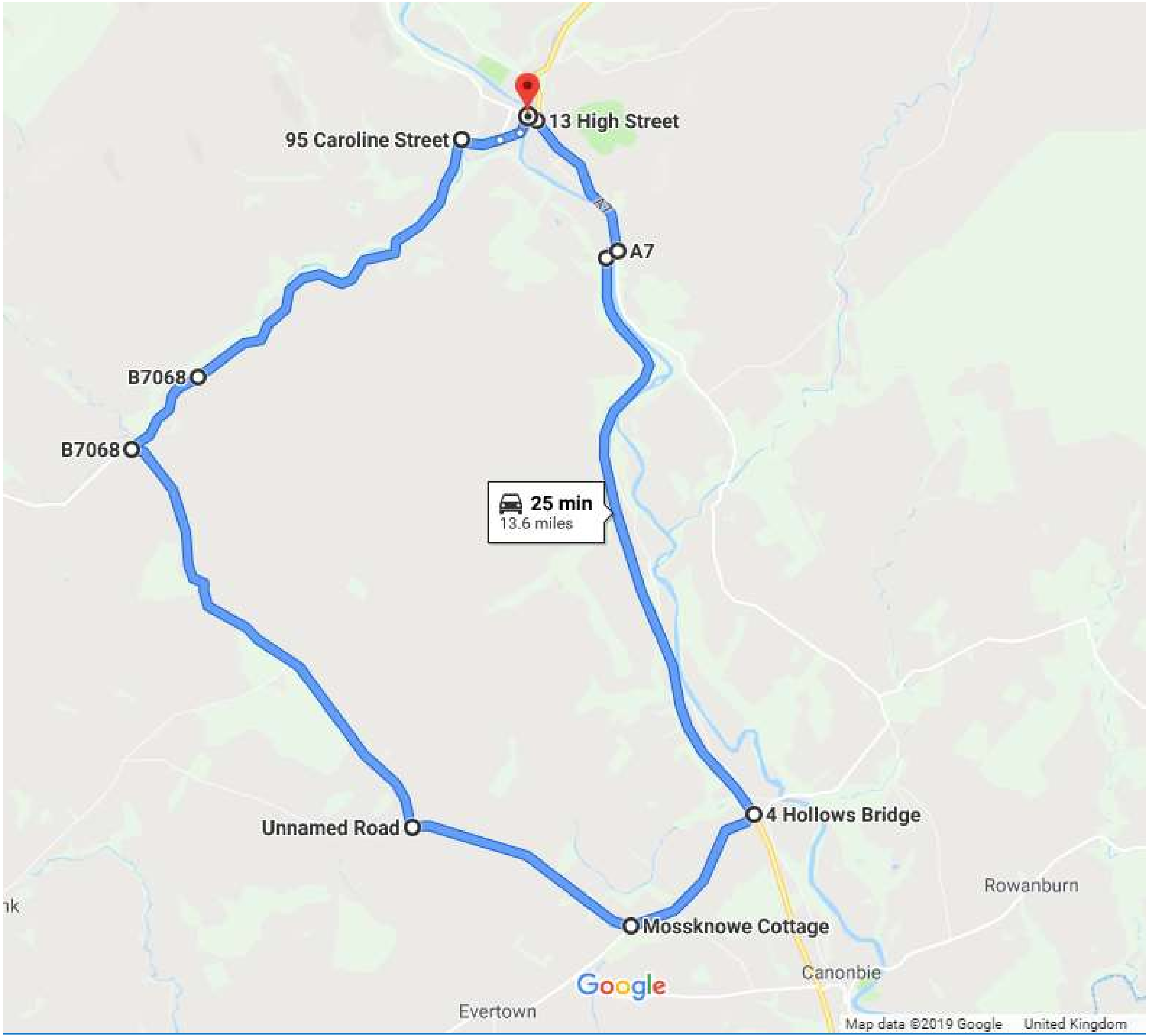

Figure 3.11: Emergency Route 2

It can be seen above that both suggested routes require traffic to use small rural roads. Whilst this is not ideal for emergency access during a flood event, the nature of the rural catchment makes it a necessity.

Emergency plans and traffic management was deemed to be a feasible action. It is recommend that future investigation of the bridges in the area is carried out to ascertain if they will flood during flood events and this information should be used to inform the final proposed emergency routes in the area.

3.3 Baseline Natural Flood Management (NFM) Assessment

A baseline NFM assessment, as described in the FRM Act 2009 Local Authority Flood Study Checklist v3, has been undertaken to identify where opportunities to restore or enhance natural processes may benefit flood risk. In accordance with current guidance in the SEPA: *Natural Flood Management Handbook*, the elements included in the assessment are:

- Catchment characterisation
- Long listing of measures

3.3.1 Catchment Characterisation

The purpose of characterising the catchment area is to develop an understanding of how the catchment currently operates under flood conditions and the areas of the catchment that contribute most to flooding. The available information to assist with this process within the study area is as follows:

- Langholm Flood Protection Scheme – Hydrology Report (RPS)
- Natural Flood Management Maps (SEPA)
- Land Cover Map 2007 (Centre for Ecology & Hydrology)
- Historical Mapping
- SEPA Morphological Dataset
- James Hutton Institute Dataset
- Interrogation of the study's hydraulic model
- "SEPA's Natural Flood Management: Opportunity Areas for Floodplain Storage" dataset

3.3.1.1 Langholm Flood Protection Scheme – Hydrology Report (RPS)

The main study catchments are shown in Figure 3.12, including the tributary catchments; the Wauchope Water and Ewes Water.

The River Esk catchment is natural and upland; it has mostly impermeable bedrock with approximately two thirds superficial deposits. The land use is predominately rough grazing with more than a third forestry with minimal flood plains.

Table 3.7: Summary of Main Catchment Descriptors

Catchment	Area (Km^2)	SAAR (mm)	PROPWET	DPSBAR (m/km)	BFIHOST	FARL
River Esk	414.53	1445	0.62	174.0	0.42	0.993
Wauchope Water	40.94	1380	0.6	150.2	0.384	1.0
Ewes Water	79.15	1391	0.6	256.6	0.48	1.0

As can be seen from Table 3.7 the main water course, the River Esk and the two sub catchments, have largely similar catchment descriptors. All three catchments can be described as having fairly low baseflow index values and could be considered to be fairly steep, suggesting the catchments would be expected to have a high proportion of surface runoff contribution to river flows. The FARL factors also suggest there is little to no attenuation within the catchments.

Figure 3.12: Catchments influencing Langholm

3.3.1.2 SEPA Natural Flood Management Maps

The natural flood management (NFM) maps (http://map.sepa.org.uk/floodmap/map.htm) identify areas where the alteration or restoration of natural features could be most effective in storing or slowing the flow of water, or in managing in stream sediment. A total of five maps are available that identify opportunity areas for a set of different NFM techniques. Each map provides a high level assessment of areas within catchments where the implementation of NFM could be most effective and merit further investigation. The runoff reduction map is discussed below, the floodplain storage and sediment management maps are discussed in Section 3.3.1.8 of this report.

The other two maps (Estuarine surge attenuation and wave energy dissipation) are not applicable to Langholm.

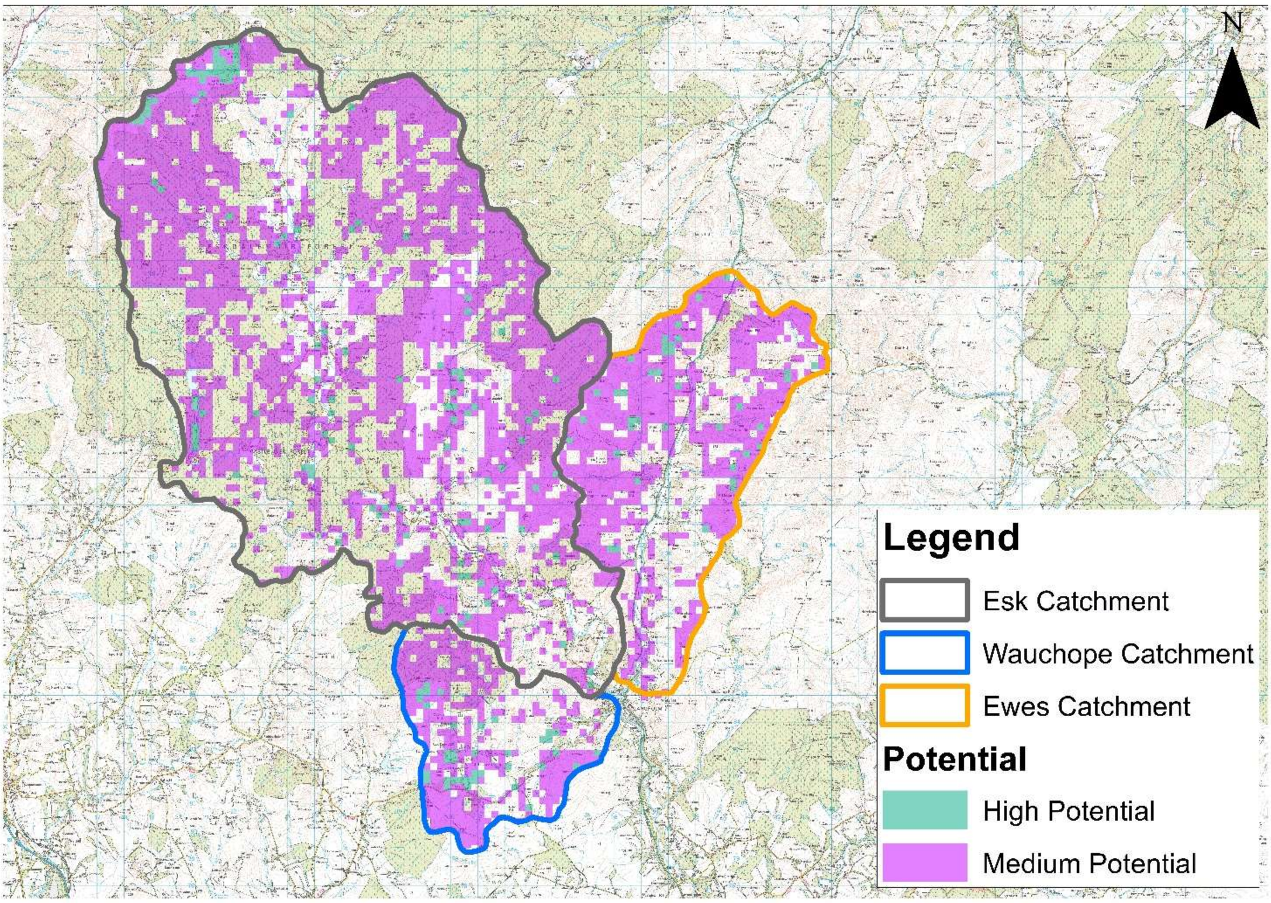

Figure 3.13: Opportunity Areas for Runoff Reduction

The Runoff reduction map indicates the areas shown in Figure 3.13, identified as having predominantly medium potential. Due to the high level nature of the assessment used to generate the SEPA Maps, site specific datasets (such as those reviewed below) can be considered to be of more benefit in identifying potential areas for NFM.

3.3.1.3 Land Cover / Land Use

Figure 3.14 shows the land cover/land use mapping for the Langholm catchments. This figure identifies the following general trends in land use within the catchment. The overall catchment area is predominantly rural with very little urban and suburban land use. The Ewes catchment has a high proportion of acid grassland while the main Esk catchment is a mixture of commercial coniferous woodland and acid grassland.

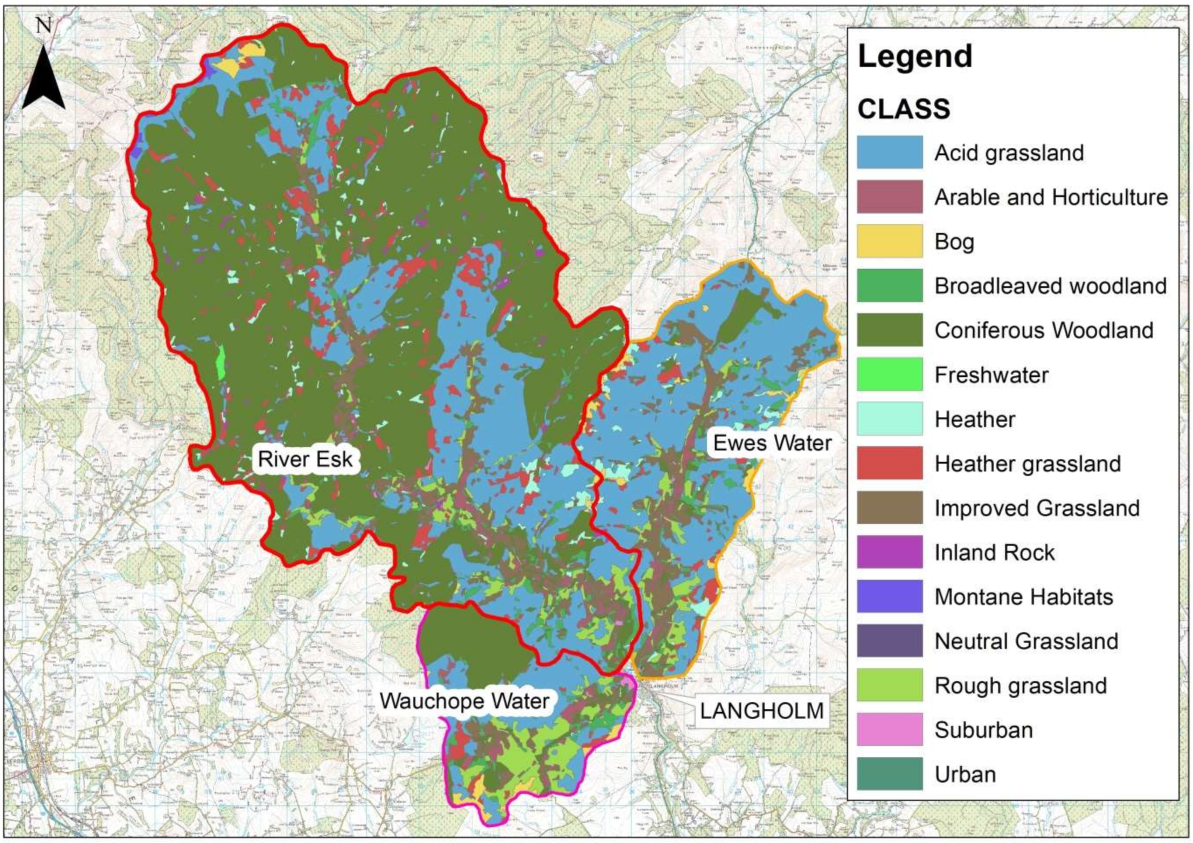

Figure 3.14: Langholm Land Use Mapping

3.3.1.4 Historical Mapping

A review of the earliest historical mapping for the overall area, 'OS One Inch, 1885-1900', was undertaken in order to identify any changes in watercourse route in the catchment upstream of Langholm, however no significant changes in the catchment over time were identified. A review of 'OS 25 Inch to the mile, 1st Edition, 1857' was also carried out to check the historic line of the watercourses as they flow through Langholm. This is supported by the NRFA website which states that there have been no known significant catchment changes.

3.3.1.5 SEPA Morphological Dataset

A review of the SEPA Morphological dataset was undertaken in order to identify if any areas of the river channels near Langholm had been re-profiled or realigned. It was identified in this dataset that no morphological changes have taken place which would influence Langholm.

3.3.1.6 James Hutton Institute Dataset

The James Hutton Institute (JHI) has complied a Land Capability for Forestry data set from the majority of areas in Scotland. This dataset was based on an assessment of the increasing degree of limitation imposed by the physical factors of soil, topography and climate on the growth of trees. This dataset was mainly created to aid *'decision making at road planning levels, as a guide for land managers and as a statement of the natural resources of the land of Britain in terms of forestry potential for the educational and general interest purposes'*.

JHI have classified land into seven suitability classes (F1-F7). For the purpose of this report, F3 and F4 have been considered as being applicable to the Langholm Catchment as areas which are included in these classes are considered potentially suitable for the addition of woodland areas. Areas classed F1/F2 – Arable Land, were screened out as they were considered too valuable to farming to be suitable for additional planting. Areas classed F5/F6/F7 were screened out as not being suitable for additional planting.

Class F3 – *'Land with good flexibility for the growth and management of tree crops.'*

Class F4 – *'Land with moderate flexibility for the growth and management of tree crops.'*

Overall there is limited suitability for the addition of forest area in the Langholm catchment. This is largely down to the large amount of forest already within the catchment, as well as the steeply sloping nature of the catchment.

Figure 3.15 below shows the Class F3 & F4 areas identified in the Langholm catchment.

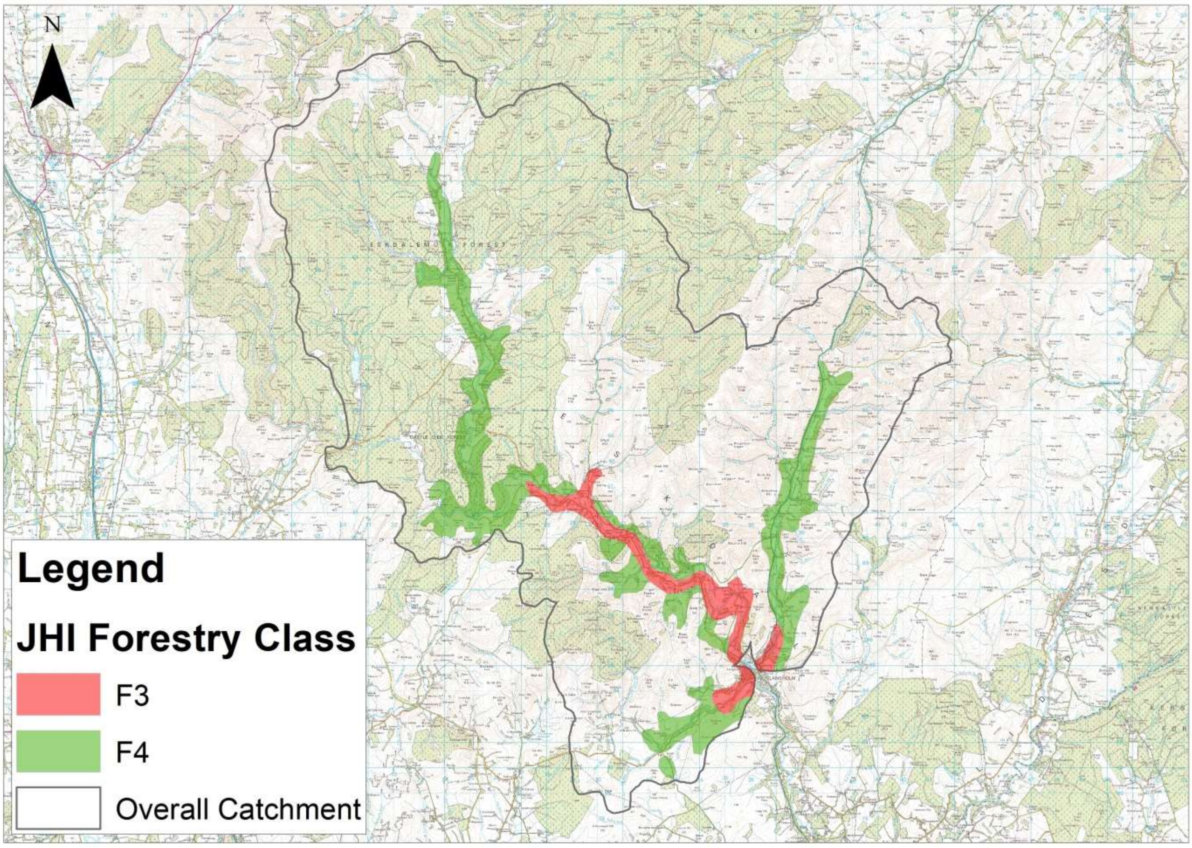

Figure 3.15: JHI Land Classification for Forestry

3.3.1.7 Hydraulic Model & SEPA online Flood Maps

From review of the hydraulic model and SEPA's online flood maps, areas of potential for planting of floodplain woodland were identified. These are illustrated in the NFM Assessment Map in Appendix G. Potential areas for floodplain reconnection were also identified through review of the hydraulic model and aerial photography. This analysis can be found in Section 3.2.3 of this report.

3.3.1.8 SEPA Flood Maps (2015) – Sediment

These include the first national natural flood management maps in Scotland showing the areas where natural techniques to help reduce flood risk could be most effective. They were produced by a high level assessment (nationwide sediment transport assessment) to identify areas where the alteration or restoration of natural features could be most effective in managing in stream sediment and merit further investigation. Figure 3.16 below shows the areas within the study area which were identified by SEPA as being high deposition areas.

As has already been stated, the SEPA data is taken from a high level study. Sediment removal and the potential positive impact it could have on flood extents was investigated in more detail in the screening of the Long List of Actions for Langholm (Section 3.1 of this report). The conclusion of this was that sediment removal would have little impact on flood extents.

The influence of sediment to flood risk was considered in Section 3.2.5. Known areas of deposition, identified from the SEPA flood maps and confirmed through site visits and surveys, are located in Langholm where flood risk is present. The removal of the sediment was modelled however the results showed that even extensive removal of sediment would have minimal impact to flood risk.

It is anticipated that the continued erosion and deposition of the rivers within the study could contribute to future flood risk in the future. Given the nature of land management in the upper catchment agricultural land and commercial forests where bare earth and soil disturbance is common, it is likely that overland runoff would be sediment laden. There is merit therefore in preventing erosion in the rivers where receptors would be put at risk in the future and reducing the amount of sediment entering the watercourses from the catchment.

Further exploration of the benefits of sediment removal would be additional work outside the scope of this study.

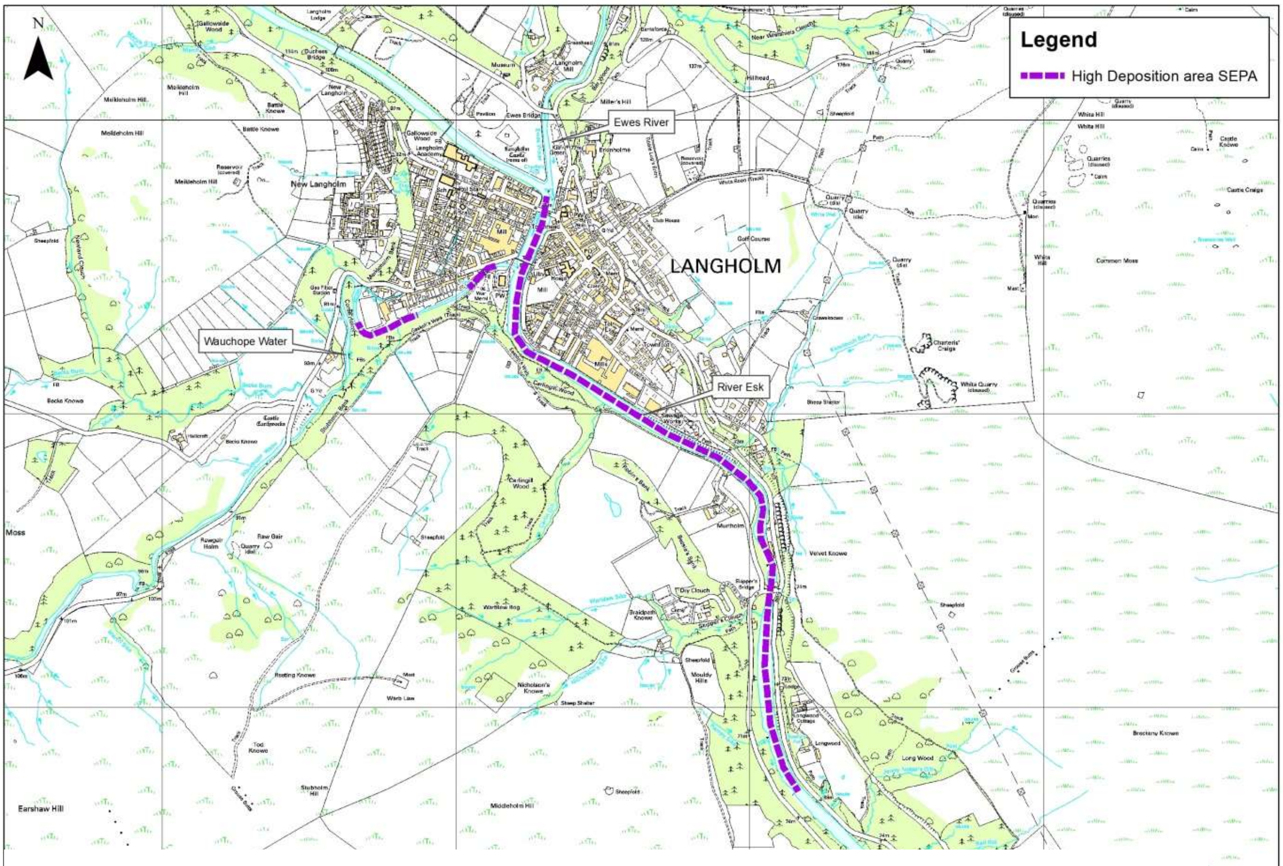

Figure 3.16: SEPA highlighted areas of high deposition

3.3.2 Long List of Measures

Based on the characteristics of the catchment as described in the previous section a long list of potential NFM measures were identified. Actions that would reduce runoff, attenuate flow and manage sediment were considered. Building on the data from previous studies and analysing datasets including, OS mapping, Aerial Photography (Google Earth), DTM, Land Cover Mapping, Wetland's Inventory, NFM Opportunity Mapping and Potential for Woodland Creation the Langholm Catchment was assessed for identification of NFM opportunities. The NFM measures which were identified as potentially being suitable for the catchments influencing Langholm are:

- Agricultural and Upland Drainage Modification (Commercial Forestry)
  - Drain Blocking
  - Managed Tree Felling
  - Buffer Strips
- Catchment Woodlands
- Instream Structures
- Floodplain Woodlands

The main output of this section is a map with potential NFM opportunities identified within the catchment included on it. This can be found in Appendix G of this report. The following section describes the NFM opportunities identified.

3.3.2.1 Agricultural and Upland Drainage Modification

A significant proportion of the Langholm catchment consists of commercial forestry. These areas are subjected to a significant amount of tree cutting and replanting and a significant proportion of the catchment can therefore lie bare of vegetation at any one time. Land is also often artificially drained in order to provide favourable conditions for tree growth. The result of this land use is a significant increase in surface runoff volumes coming from those areas.

Blocking the man-made drains in strategic locations and managed tree felling with consideration to flood risk, could have positive effects on surface runoff volumes. The addition of buffer strips between felled areas and streams would also help reduce runoff from these areas.

Figure 3.17 shows an example of commercial forestry in the Langholm catchment.

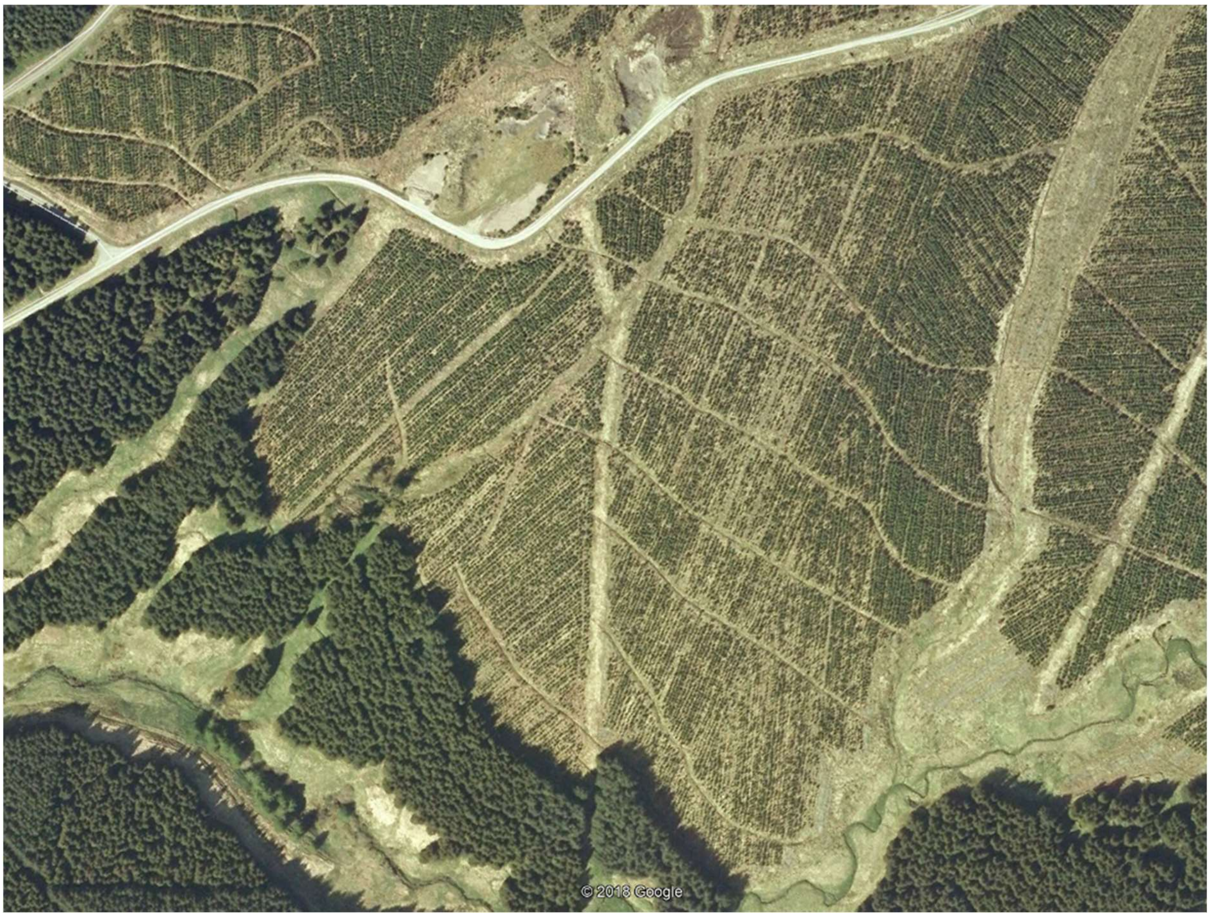

Figure 3.17: Commercial Forestry near Langholm

3.3.2.2 Catchment Woodlands

Catchment Woodland creation was considered as a measure that could reduce runoff. Studies have shown that woodlands can be effective in reducing runoff as they intercept precipitation via their tree canopy and intercept runoff by providing a barrier to the flow and increasing infiltration into the ground through their root system. The need to increase the amount of woodland areas has been recognised. The James Hutton Institute produced a Land Capability for Forestry dataset. This dataset was reviewed within the Langholm Catchment and refined by the following criteria:

- Existing woodland areas are excluded from the woodland potential dataset. A review of these woodlands was carried out and areas where deforestation has taken place or where woodlands are sparsely populated were added to this potential measure.
- Areas unsuitable for tree planting, such as crags and very steep areas were also discounted as potential areas.
- Areas of high quality farm use were identified and given priority over potential woodland creation. These areas have been marked as low potential for woodland planting in the NFM opportunities map.

Areas which were identified as being suitable have been highlighted in the NFM measure map in Appendix G.

3.3.2.3 Instream Structures

Instream Structures have the potential to reduce flood flows by slowing the water down and forcing it out into the floodplain where it would be stored or slowed further. Barriers can consist of woody debris dams, or rock/boulder weirs. A review was carried out of the watercourses in the Langholm. All reaches that were considered suitable were highlighted in the NFM opportunity map presented in Appendix G. Reaches discounted included those where the river becomes too large and an engineered weir solution would be required to achieve the same impact. In addition, reaches that are too steep and have no floodplain into which flood water could be forced, would have limited potential to reduce flood flow and were therefore also discounted. Existing structures such as bridges, properties and settlements were also considered as, increased floodplain flow nearby to these areas could increase the flood risk to these receptors. Many of the reaches identified are located within a natural valley with a well-defined floodplain. There are therefore good opportunities to implement this measure within the Langholm catchment.

3.3.2.4 Floodplain Woodland

A complimentary measure to the instream structures is the addition of floodplain woodlands. These woodlands are located within the floodplain of the river and act as a barrier to the water flowing through the floodplain. A review was carried out to identify areas where floodplain woodlands would be suitable. Areas where a defined floodplain was identified and where the land was not considered valuable agricultural land or developed were considered suitable. Areas which were identified as being suitable have been highlighted in the NFM measure map in Appendix G.

Figure 3.18 shows an example of a location within the Esk catchment which would be suitable for additional floodplain woodland.

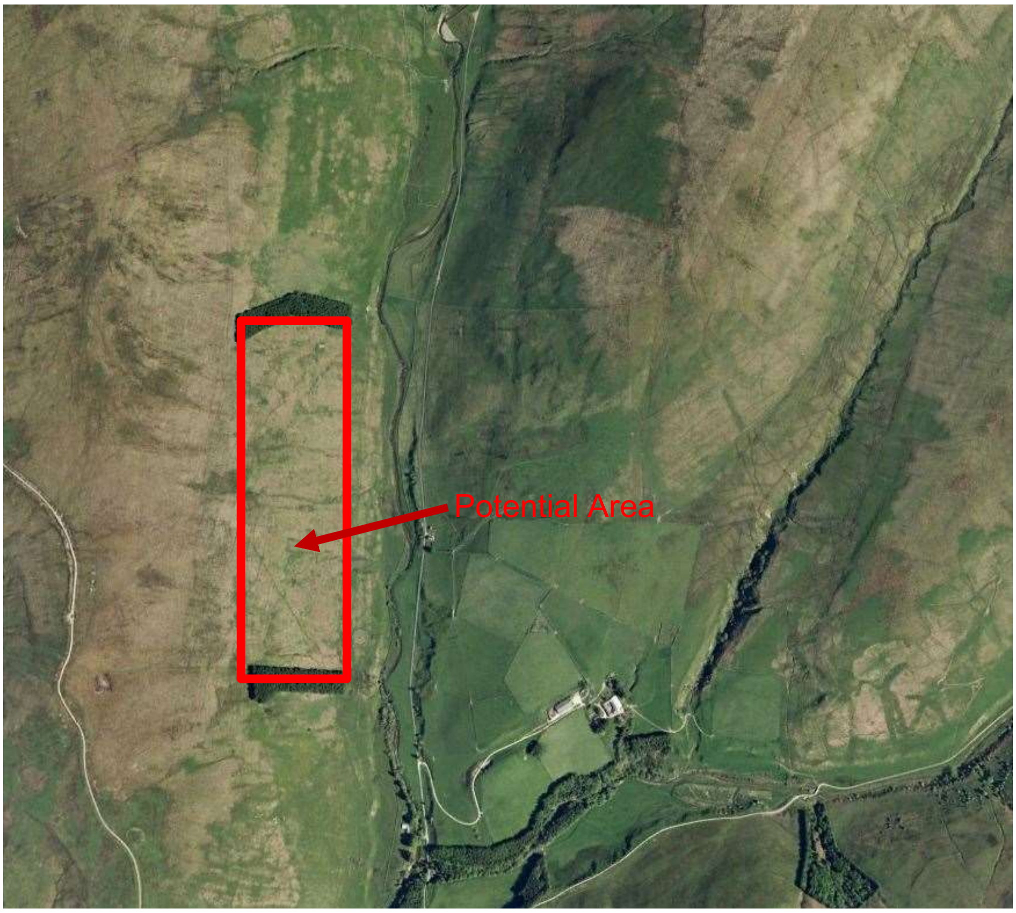

Figure 3.18: Potential Location for Floodplain Woodland

3.3.3 Quantifying NFM Effectiveness

Quantifying the reduction to flood level brought about by NFM measures in a large catchment like Langholm is difficult. It can be seen from the Baseline NFM Map in Appendix G that:

- 51% of watercourses in the catchment are suitable for instream structures
- Upland drain blocking may be suitable in an area of 179 km^2
- Floodplain woodlands may be viable in a 5.31 km^2 area*
- 11.91 km^2 of the catchment may be suitable for catchment woodland measures*

*Combined Woodland Potential of 17km^2 = 4% of the catchment. This means only 4% of the catchment has the potential to reduce flows using woodland planting.

Section 1.2.2 of the Environment Agency (EA) – *Working with Natural Processes Evidence Directory states* 'The effectiveness of NFM measures is site-specific and depends on many factors including the location and scale at which they are used." Data recorded from previous studies where NFM has been implement is not transferable to this scheme.

Of the four NFM measures highlighted as being potentially suitable for the Langholm catchment, there is insufficient data to quantify the effect that any of them will have on flows within the catchment. The only measure discussed in the EA –*Evidence Directory,* as having a quantifiable effect on flood flows is Woodland Planting. The Directory suggests that this can have an effect in the range of 5% to 65%.

The EA Directory classifies the Langholm Catchment as a large catchment and the design event as a large flood. This means that the likely reduction in flow brought about by NFM in the catchment, would be at the lower end of the range mentioned above.

A 5% reduction in flow would take approximately 16% (57no.) of properties out of the flood extent in the 0.5% AEP (1 in 200 year) design event. This reduction may result in an approximate benefit of £1.6million.

High level costing (using the SEPA Unit Cost Database), of providing Upland Drain Blocking to 180km^2 of the catchment and planting 17km^2 of 'Productive conifer' in the catchment shows that these measures alone could cost £40million (indicative costs derived from the SEPA Unit Cost Database).

3.3.4 Conclusion

The evidence provided in the above section of the report indicates that if a reduction of 5% in flood flows could be achieved by NFM measures, then a significant reduction in the number of properties impacted by flooding in Langholm could be achieved.

The issue however with this reduction is that the extent to which NFM measures would need to be implemented within the catchments influencing Langholm, to achieve a 5% flow reduction is unknown. This is due to the current industry wide lack of knowledge on how to quantify the effectiveness of NFM measures.

3.4 Shortlist of Actions: Developing Options

The screening of actions identified all feasible actions from the long-list to form a shortlist. From this shortlist, viable options were developed that would meet the objectives set out in the Section 2. Table 3.8 Summary of Viable Options, below summarises the viable options.

The screening process identified that the only standalone action capable of providing flood protection to Langholm in a 0.5% AEP (1 in 200 year) flood event were direct defences. Options were therefore developed as combinations of direct defences and other actions.

All options would have flood forecast & warning, self-help and emergency plans & traffic management included in them.

Table 3.8: Summary of Viable Options

Option	Descriptions of Option
Structural Option 1	Direct Defences
Structural Option 2	Direct Defences & Flood Diversion Channel
Structural Option 3	Direct Defences & Re-routed Channel

3.4.1 Structural Option 1

The principle Flood Risk Management Action in this option would be direct defences. The alignment of the defences would be dictated by the space between the river and receptors. A general rule was adopted where the defence would be placed as far away as possible from the river, while providing a barrier to the receptors at risk. Space would also dictate if flood embankments could be proposed or whether walls would be required

Structural Option 1 consists of 931m of earth embankment, 701m of reinforced concrete retaining wall and 549m of piled wall with a reinforced concrete top.

PLP will be provided to the Church of Scotland at the confluence of the Wauchope Water and River Esk.

An Emergency Plan and Traffic Management would consider which roads would be at risk of flooding and identify access routes through lower risk areas. These would allow emergency services to access both sides of Langholm during a flood event.

A drawing of Structural Option 1 is included in Appendix H.

3.4.2 Structural Option 2

This option consists of the same length of defence as Option 1 in combination with a relatively large bypass channel. The bypass channel would be constructed to the south of the Church of Scotland and would be dry in normal flow conditions up to a 10% AEP event. The effect of this bypass would be to reduce the required direct defence heights in the centre of Langholm and along the Wauchope Water.

The bypass channel would be incorporated into the existing park area near the church. During normal flow conditions the bypass could be used as a public amenity area.

PLP will be provided to the Church of Scotland at the confluence of the Wauchope Water and River Esk

An Emergency Plan and Traffic Management would consider which roads would be at risk of flooding and identify access routes through lower risk areas. These would allow emergency services to access both sides of Langholm during a flood event.

A drawing of Structural Option 2 is included in Appendix H.

3.4.3 Structural Option 3

The main feature of Option 3 would be the realigning of the Wauchope water to the south of the Church of Scotland. This would require the creation of a new 190m long river channel and the infilling of the existing Wauchope channel to the north of the church.

The realigned channel reduces the required defence heights along the Wauchope Water and in the centre of Langholm. The realignment of the channel would also allow the direct defences along Caroline Street to be earth embankments rather than flood walls.

Overall the option would consist of 1101m of earth embankment, 483m of reinforced concrete wall and 549m of piled wall with a reinforce concrete top.

PLP will be provided to the Church of Scotland at the confluence of the Wauchope Water and River Esk

An Emergency Plan and Traffic Management would consider which roads would be at risk of flooding and identify access routes through lower risk areas. These would allow emergency services to access both sides of Langholm during a flood event.

A drawing of Structural Option 3 is included in Appendix H.

3.4.4 NFM

A long list of NFM opportunities have been identified and detailed in Section 3.3. This long list was not shortlisted as part of this study. This would further assess the effect on flood risk and the additional benefits (and dis-benefits) provided. As such it is not possible to appraise and compare NFM with other potential solutions, either as a standalone option or incorporated into a structural option. NFM has therefore been considered further in Section 5 where recommendations to support option development are detailed.

3.4.5 Describe and Value: Appraising the Options

The options described in Section 3.4 were appraised using Guidance in the SEPA document: *Flood and Coastal Erosion Risk Management appraisal guidance.* The following components were assessed:

- Estimates of flood risk management benefits
- Wider positive and adverse impacts
- Adaptability to climate change and other future flood risk
- Whole life cost
- Uncertainty in costs and benefits

This can be seen in Table 3.9.

Table 3.9: Appraisal Table

Option	Baseline	Structural Option 1 – Direct Defence	Structural Option 2 – Flood Diversion + Direct Defences	Structural Option 3 – Channel Re-route + Direct Defences
Overview/Description	The Option to continue with current flood practice in Langholm. This includes the use of the SEPA Flood Forecast and Warning System in operation in the area, demountable defences to existing river walls in the town centre and flood evacuation.	931m of Earth Embankment, 501m of Reinforced Concrete Retaining Wall Type 1, 549m of Piled Wall with a Reinforced Concrete top and 200m of Reinforced Concrete Retaining Wall Type 2. PLP provided to the CoS. Emergency Plan & Traffic Management Plan	931m of Earth Embankment, 501m of Reinforced Concrete Retaining Wall Type 1, 549m of Piled Wall with a Reinforced Concrete top and 200m of Reinforced Concrete Retaining Wall Type 2 and a 200m long Flood Diversion Channel. PLP provided to the CoS. Emergency Plan & Traffic Management Plan	1101m of Earth Embankment, 283m of Reinforced Concrete Retaining Wall Type 1,549m of Piled Wall with a Reinforced Concrete top and 200m of Reinforced Concrete Retaining Wall Type 2 and a 190m long Re-routed Channel section. PLP provided to the CoS. Emergency Plan & Traffic Management Plan
Technical issues	None	None known	Spill weir construction between the Wauchope channel and the flood diversion channel.	Permission to re-route the river channel.
Assumptions and uncertainties	None	Utility services locations unknown at this time. Ground conditions unknown. A standard freeboard (0.5m for walls, 0.6m for embankments) has been assumed.	Utility services locations unknown at this time. Ground conditions unknown. A standard freeboard (0.5m for walls, 0.6m for embankments) has been assumed.	Utility services locations unknown at this time. Ground conditions unknown Assumed that permission will be granted to allow the Wauchope Water channel to be re-routed. A standard freeboard (0.5m for walls, 0.6m for embankments) has been assumed.
Approaches to adaptation	The Baseline Option provides no scope for future adaption.	Unless accounted for in the design and build, flood walls would have limited adaption capabilities to account for climate change. Alternative FRM measures would be required.	Unless accounted for in the design and build, flood walls would have limited adaption capabilities to account for climate change. Alternative FRM measures would be required. The diversion channel could be widened in the future to convey more flow however this would require new or additional spill weirs.	Unless accounted for in the design and build, flood walls would have limited adaption capabilities to account for climate change. Alternative FRM measures would be required. The re-routed channel could be widened in the future to convey more flow.
Cost	-	£8,093,632	£8,609,384	£7,896,059

Category	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties
Economic Impacts												
Properties	244 properties as well as the Buccleuch Estate and Langholm Church of Scotland would be flooded in a 0.5% AEP (1 in 200 year) flood event.	PV damages: £14,360,053	-	244 properties afforded protection up to the 0.5% AEP (1 in 200 year) event. Protection not provided to Buccleuch Estate properties to the north of Langholm and Langholm Church of Scotland.	PV damages: £2,201,077	-	244 properties afforded protection up to the 0.5% AEP (1 in 200 year) event. Protection not provided to Buccleuch Estate properties to the north of Langholm and Langholm Church of Scotland.	PV damages: £2,201,077	-	244 properties afforded protection up to the 0.5% AEP (1 in 200 year) event. Protection not provided to Buccleuch Estate properties to the north of Langholm and Langholm Church of Scotland.	PV damages: £2,201,077	-

Category	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties
Vehicles	Vehicles likely to be damaged and written off at a flood depth of 0.35m.	PV damages: £191,202	Average number of cars per household ~ 1.16. Vehicle cost of £3,600.	Vehicles likely to be damaged and written off at a flood depth of 0.35m.	PV damages: £191,202	Average number of cars per household ~ 1.16. Vehicle cost of £3,600.	Vehicles likely to be damaged and written off at a flood depth of 0.35m.	PV damages: £191,202	Average number of cars per household ~ 1.16. Vehicle cost of £3,600.	Vehicles likely to be damaged and written off at a flood depth of 0.35m.	PV damages: £191,202	Average number of cars per household ~ 1.16. Vehicle cost of £3,600.
Transport	Disruption to main roads in Langholm. No way to cross the Esk in Langholm during flood events. (See Receptors table).	Disruption to Langholm	-	All roads protected, however access across bridges may be impacted during high flows.	Impacts not valued	-	All roads protected, however access across bridges may be impacted during high flows.	Impacts not valued	-	All roads protected, however access across bridges may be impacted during high flows.	Impacts not valued	-
Infrastructure	Disruption to Waste Water treatment plant. Disruption to water mains and Scottish Gas plant.	Disruption to services.	Impacts not valued.	Protection not provided to the SGN Gas Station.	Impacts not valued	-	Protection not provided to the SGN Gas Station.	Impacts not valued	-	Protection not provided to the SGN Gas Station.	-	-
Environmental Impacts												
Flora Fauna	No significant impacts expected.	-	-	Trees and bushes along line of defence will be removed in year 1 and replaced to regenerate over lifespan of the option.	Impacts not valued	-	Trees and bushes along line of defence will be removed in year 1 and replaced to regenerate over lifespan of the option. Loss of existing trees and shrubs through the creation of the flood diversion channel.	Impacts not valued	-	Trees and bushes along line of defence will be removed in year 1 and replaced to regenerate over lifespan of the option. Loss of existing trees and shrubs through the creation of the re-routed channel. Loss of flora/fauna from removing watercourse. Potential new wetland area could be created near the existing Wauchope Water channel line.	Impacts not valued	-
Soil	No significant impacts expected.	-	-	No significant impacts expected	-	-	No significant impacts expected	-	-	No significant impacts expected	-	-
Water	No significant impacts expected.	-	-	No significant impacts expected	-	-	Hydromorphological conditions may change. WFD should be consulted.	Impacts not valued	-	Hydromorphological conditions may change. WFD should be consulted.	-	-

Category	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties	Description and quantification of impacts	Value of impacts	Assumptions and uncertainties
Use of natural resources	No significant impacts expected.	-	-	No significant impacts expected	-	-	No significant impacts expected	-	-	No significant impacts expected	-	-
Climatic factors	No significant impacts expected.	-	-	Carbon emissions significant in year 1 due to construction.	Impacts not valued	-	Carbon emissions significant in year 1 due to construction.	Impacts not valued	-	Carbon emissions significant in year 1 due to construction.	Impacts not valued	-
Landscape	No significant impacts expected.	-	-	Changes to landscape along a small stretch of the river corridor from the addition of embankments and flood walls.	Impacts not valued	-	Significant landscape changes to localised area expected along river corridor brought about by the diversion channel and walls/embankments.	Impacts not valued	-	Significant landscape changes to localised area expected along river corridor brought about by the re-routed channel and walls/embankments.	Impacts not valued	-
Social Impacts												
Way of life	During and post flooding there would be loss of transport routes and recreational sites for the community. Flooding of residential homes and businesses would impact on owner's health and wellbeing.	-	-	Way of life significantly improved through protection of properties, recreational sites and transport routes. Presence of high flood wall along the river corridor will disconnect the river from the town.	Impacts not valued	-	Way of life significantly improved through protection of properties, recreational sites and transport routes. New diversion channel could facilitate the new community park. Presence of flood wall along the river corridor will disconnect the river from the town although the diversion channel would reduce the required defence height.	Impacts not valued	-	Way of life significantly improved through protection of properties, recreational sites and transport routes. Possible impacts to proposed community park. Presence of flood wall along the river corridor will disconnect the river from the town although the re-routed channel would reduce the required defence height.	Impacts not valued	-
Culture	Damage to listed buildings.	-	-	Protection provided to listed buildings.	Impacts not valued	-	Protection provided to listed buildings	Impacts not valued	-	Protection provided to listed buildings	Impacts not valued	-
Community	Impacts to community recreation sites. Disruption to general life during and post flood events.	-	-	Protection not provided to the War Memorial park.	Impacts not valued	-	Protection not provided to the War Memorial park.	Impacts not valued	-	Protection not provided to the War Memorial park.	Impacts not valued	-

4 STAGE 3: COMPARE AND SELECT THE MOST SUSTAINABLE OPTIONS

In order to select the most sustainable option a decision was made based on the appraisal detailed in Section 3.4 which considered the economic, social and environmental impacts, whole life cost, and consideration of the risk and uncertainty. The following questions were considered in this comparison and selection:

- Does the option meeting the objectives?
- Does the option represent best value for money?
- Does the option deliver multiple benefits? What are the adverse impacts?
- What are the uncertainties and robustness in the appraisal? What are the risks of implementation?

4.1 Does The Option Meet The Objectives?

Table 4.1 summarises the objectives identified in Section 2.4 and whether they would be met by implementing each option. The objective to identify the option with best value for money has been omitted from this section and will be discussed in Section 4.2.

Table 4.1: Summary of options against objectives

Objective	Option		
	Structural Option 1	Structural Option 2	Structural Option 3
To provide a 0.5% AEP (1 in 200 year) SoP	✓	✓	✓
Reduce flood risk	✓	✓	✓
Avoid increase in flood risk	✗	✓	✓
Access to key receptors maintained	✓	✓	✓

Note: An increase in flood risk is experienced in Option 1 as the addition of walls along the Wauchope increases the height of flood water around the Church of Scotland grounds.

4.2 Does The Option Represent Best Value For Money?

RPS undertook a benefit-cost analysis to demonstrate the economic case for the identified options. This involved an assessment of the benefits (i.e. reducing flood impact) and the costs of the options over a 100 year design life span. This approach ensures that Dumfries and Galloway Council has a robust economic argument which shows that the preferred option provides best value for money.

Full details of the Economic Appraisal including damage assessment assumptions and option costing are presented in Appendix B and E. Table 4.2: Option Economic Summary, below summarises the results of the Economic Appraisal.

Table 4.2: Option Economic Summary

	Structural Option 1	Structural Option 2	Structural Option 3
Costs			
Capital costs	£4,037,082	£4,289,239	£3,926,663
Optimism Bias Adjustment (60%)	£3,035,112	£3,228,519	£2,961,022
Preliminary & Enabling Costs	£877,460	£932,266	£853,461
Sub - Total Cost	£7,949,654	£8,450,024	£7,741,146
Maintenance Costs (NPV over 100 years)	£143,978	£159,361	£154,913
Total Present Value Costs	£8,093,632	£8,609,385	£7,896,059
Damages			
Present Value Damage (Properties and Vehicles)	£11,361,835	£11,361,835	£11,361,835
Present Value Damage Avoided (Properties and Vehicles)	£9,157,321	£9,157,321	£9,157,321
Benefits			
Intangible Benefit	£1,123,717	£1,123,717	£1,123,717
Total Present Value Benefit	£10,281,038	£10,281,038	£10,281,038
Benefit Cost Ratio			
Average benefit/cost ratio	**1.27**	**1.19**	**1.30**

4.4 Does The Option Deliver Multiple Benefits? What Are The Adverse Impacts?

The tables in Section 3.4.5 describe the positive and negative impacts which would result from the implementation of each of the options. The three options were identified as having similar economic impacts. However the options differed on their potential environmental and social impacts.

Option 1 would require the highest wall heights in the centre of Langholm. These walls could have negative social impacts on the locals in Langholm. RPS aims to reduce the required height of direct defences through the centre of Langholm. The addition of a bypass / realigned channel present in Options 2/3 would allow the heights of the direct defences to be decreased, thus improving potential social impact.

Option 2 has the potential to most positively impact socially as it would both reduce direct defence heights The new diversion channel would be constructed in such a way as to improve public amenity in the area of the existing park.

Option 3 would cause significant hydromorphological changes to the Wauchope River and hence the surrounding area. This could have significant environmental impacts in the short to medium term in the area and may result in a reduction in the amount of sediment building up at the Wauchope Water footbridge.

4.5 What Are The Uncertainties And Robustness In The Appraisal? What Are The Risks Of Implementation?

The Tables in Section 3.4.5 identified the associated uncertainties of each option. These are uncertainties associated with the technical difficulty and cost of Structural Options 1, 2 and 3 due to the space constraints in which the options would be constructed. Uncertainty in ground conditions are present in all of the options. All three options make assumptions about the type of wall required in each location.

Options 2 and 3 have the additional uncertainty in the ability to construct a new channel through the parkland to the south of the Church of Scotland. The hydromorphological impacts of realigning the Wauchope Water in Option 3 are unknown.

At this stage of the process the impact of utility services, other structures, traffic restrictions and ground conditions are unknown for all three options.

There is uncertainty in all three options regarding the use of PLP at the Church of Scotland. This requires correct use during a flood event. To account for this, the calculated benefit is factored to assume satisfactory deployment in 75% of flood events.

4.6 Preferred Option

Using the criteria discussed in the previous sections of this report, Table 4.3 was produced. Options were scored from 1 to 3 against the set criteria in order to produce a preferred option.

Table 4.3: Summary of most sustainable option in Study Area

	Order of performance (1 to 3)		
	Structural Option 1	**Structural Option 2**	**Structural Option 3**
Meets objectives	2	3	3
Value for money	3	3	3
Impacts	2	3	2
Uncertainty & risk	3	2	1
Total	**10**	**11**	**9**

This table shows that when every criterion is given equal weighting Structural Option 2 is the most sustainable solution.

An impacts map of the preferred option is included in Appendix I of this report. At the downstream extent of the town there is a difference in flow between the undefended and defended scenario for the design event of 0.3%. The difference in water depths are similarly insignificant throughout except at the proposed diversion channel, which is to be expected. The preferred option does not increase the flood risk to receptors within the town or downstream of it.

4.6.1 Buccleuch Community Park

During the creation of this report, RPS were aware of the Langholm, Ewes and Westerkirk Community Council proposal to develop a park area to the south west of Langholm Church of Scotland (near existing playpark). RPS recognises the strong public support for this scheme and the positive social benefits it will bring to the area.

Due to this, RPS will work with the Community Council to incorporate the proposed park area into the flood scheme.

4.6.2 Variation to Preferred Option

A potential variation to the preferred option would be to provide protection to the three at risk properties along the Townhead Road via property level protection (PLP) rather than direct defences. This layout can be seen in Figure 4.1 below.

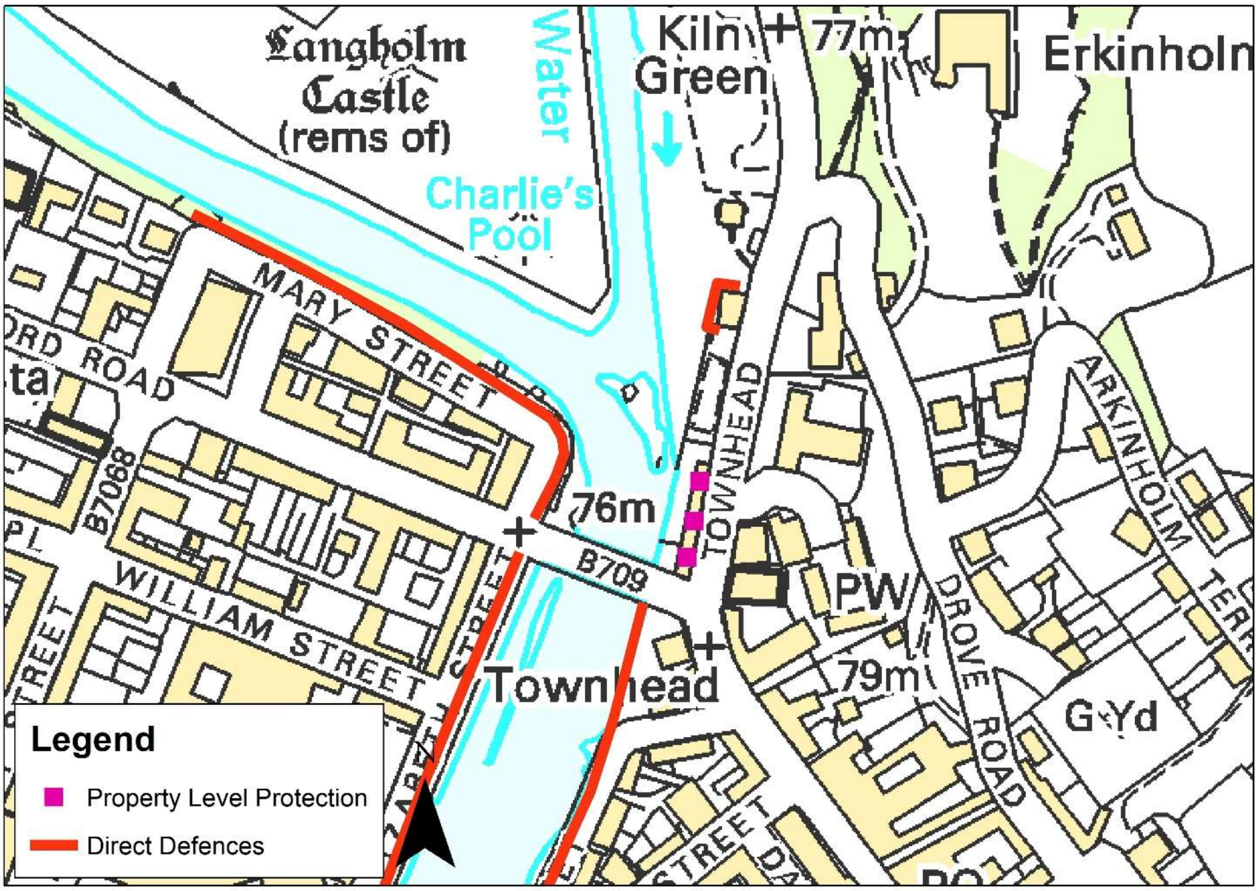

Figure 4.1: PLP Variation

High level whole life costing, using the SEPA Unit Cost Database indicates that providing PLP to these properties will cost £133,188. Providing protection to the same three properties by direct defences costs approximately £435,341.

It should be noted however that PLP will not provide the same level of protection as direct defences and therefore the numerical, social and environmental benefits would decrease.

5 RECOMMENDATIONS TO SUPPORT OPTION DEVELOPMENT

During the analysis undertaken in developing this report, a number of recommendations have been made for further work to facilitate the development of a flood alleviation scheme in Langholm. For clarity, these recommendations are summarised below in the order that they would be expected to be carried out:

- It is recommended that the hydraulic model is reviewed and updated prior to the detailed design of the flood alleviation scheme to account for the current hydraulic regime at that time with more detailed information on the roughness coefficients, to provide increased confidence in the model outputs.
- Should the preferred option be progressed, or any option that includes direct defences, analysis should be carried out to quantify the uncertainties which will inform freeboard allowance. The EA Fluvial Freeboard Guide should be referred to when carrying out this assessment.
- The level of uncertainty associated with the preferred option should be reduced such as identifying utility service assets and carrying out a ground investigation.
- It is recommended that NFM is further considered during future stages of any Langholm flood protection project in order to potentially realise some of the other benefits that NFM offers e.g. improvements in biodiversity, water quality and carbon storage and its potential to reduce flood risk. This may be included within the preferred option to ensure multiple benefits are realised.
- It is recommended that additional investigation should be carried out on the effects of sediment transport and deposition in the watercourses influencing the study area.
- It may be possible to improve the Flood Forecast and Warning System through utilisation of the modelling carried out as part of this study. This could provide information on timing and sequencing of flooding which would allow recommendations to be made on when evacuations or other actions should be initiated.