Appendix A

Flood Extent and Receptor Drawings

Flood Receptors Map

N

Legend

- Bridges

SW Assets

- CSO
- SEWAGE WORKS

Utilities

- ELECTRICITY SUB STATION
- Gas Station
- Business and Industrial Areas
- Recorded Momuments
- Roads
- Listed Buildings
- ConservationAreas_region

Properties in 0.5% AEP Flood Extent

- Comercial
- Resdential
- 0.5% AEP Flood Extent

0 75 150 300 450 600 Meters

Appendix B

Damage Assessment Guidelines and Methodology

DAMAGE ASSESSMENT GUIDELINES AND METHODOLOGY

LANGHOLM FLOOD PROTECTION SCHEME

IBE1511
Damage Assessment
Guidelines and Methodology
F01
5th March 2020

Contents

Tables

Figures

1 DAMAGE ASSESSMENT GUIDELINES

The RPS methodology to damage assessments follows the guidance in “Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal" (Penning-Rowsell, *et al.*, 2013). This book is a successor to and replacement of the highly respected manual and handbook “The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Flood Hazard Research Centre, Middlesex University, UK, 2005). This document was often referred to as the ‘Multi-Coloured Manual’ (MCM).

The new manual draws on collaboration between the Flood Hazard Research Centre, the Environment Agency, Defra and other stakeholders. Its use, accompanied by the MCM-Online, has been recommended for benefit assessment as part of a flood and coastal erosion risk management appraisal.

The MCM is a result of research carried out by Middlesex University Flood Hazard Research Centre and provides data and techniques for assessing the benefits of flood risk management in the form of flood alleviation. The MCM has focused on the benefits that arise from protecting residential property, commercial property, and road disruption amongst other areas as experience has shown that these sectors constitute the vast majority of the potential benefits of capital investment.

Based on this research the MCM provides depth damage data for both residential and commercial properties. For certain depths of flood water, a monetary damage has been assigned to a property. This damage is a combination of the likely items within the building and the building structure itself. The damage to each property is dependent on the property type; as such the MCM has categorised both the residential and commercial properties. An example of depth damage data for residential properties is shown in Figure 1.1. Property damages are available for a number of different flood sources, including fluvial, coastal surge and wave overtopping. The appropriate datasets are sourced for the applicable flood mechanism/s which is assessed for the subject area.

Long Duration Major Flood Storm No Warning (2018-2019 Price base)																	
MCM Direct damage data (£). Depth in metres (m) - Initial Appraisal																	
Property-Type	MCM code	Property Type - Age	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
Detached	111	pre-1919 Detached	2,985	9,652	38,738	54,563	73,743	88,529	97,789	103,324	110,718	123,539	134,284	147,875	156,259	165,834	176,738
	112	1919-1944 Detached	1,517	3,905	15,295	23,657	33,163	40,802	44,671	48,013	51,600	56,959	62,357	70,992	75,361	80,037	85,487
	113	1945-1964 Detached	1,426	4,416	19,283	28,982	39,797	48,224	52,561	56,143	59,713	64,555	69,318	78,396	83,476	89,185	95,712
	114	1965-1974 Detached	1,223	3,734	14,668	22,311	31,329	38,037	41,951	45,144	47,956	53,036	57,180	64,682	68,816	72,567	77,461
	115	1975-1985 Detached	1,157	3,754	15,846	23,805	33,863	41,514	46,516	50,358	53,257	58,727	63,550	72,068	75,977	79,663	83,875
	117	utility Detached	901	1,832	5,300	6,790	9,142	10,858	12,964	14,872	16,646	20,146	22,882	27,862	30,647	33,054	35,568
	118	post-1985 Detached	1,113	3,727	16,172	24,842	34,854	43,816	48,895	52,761	55,506	61,046	66,004	74,608	78,280	81,812	85,751
Semi-detached	121	pre-1919 Semi-Detached	1,842	3,194	11,434	18,040	25,324	31,437	34,525	36,722	39,037	43,798	47,635	53,655	56,683	60,283	64,617
	122	1919-1944 Semi-Detached	1,964	4,056	13,827	21,418	29,080	35,278	38,316	40,751	43,258	47,182	50,431	57,092	60,459	64,094	68,140
	123	1945-1964 Semi-Detached	1,964	4,056	13,758	21,340	28,999	35,192	38,224	40,656	43,163	47,082	50,325	56,981	60,348	63,982	68,028
	124	1965-1974 Semi-Detached	978	2,691	10,657	17,070	24,137	29,902	33,348	36,177	38,876	43,016	46,706	53,347	57,264	61,751	66,491
	125	1975-1985 Semi-Detached	924	2,327	9,797	16,271	23,367	28,910	32,248	34,741	36,614	40,102	42,803	48,065	50,417	52,507	54,851
	127	utility Semi-Detached	903	1,792	5,225	6,675	8,790	10,287	12,017	13,492	14,907	18,048	20,401	24,873	27,098	29,127	31,363
	128	post-1985 Semi-Detached	882	2,191	10,056	17,238	24,287	31,035	34,379	36,819	38,492	41,908	44,581	49,661	51,799	53,774	55,896
Terrace	131	pre-1919 Terrace	1,834	3,302	11,953	18,806	26,141	32,502	35,796	37,994	40,414	43,828	46,929	53,090	55,292	58,341	61,582
	132	1919-1944 Terrace	2,008	4,103	14,426	22,471	31,496	37,603	40,546	43,003	45,350	48,967	51,664	57,478	60,068	62,500	65,612
	133	1945-1964 Terrace	1,209	2,254	7,406	9,893	13,480	16,242	18,129	19,957	21,154	22,981	24,568	28,161	29,304	30,166	31,316
	134	1965-1974 Terrace	1,201	3,011	11,719	18,740	26,357	31,751	34,880	37,587	39,881	43,407	46,613	54,343	57,118	59,495	62,416
	135	1975-1985 Terrace	788	2,043	8,834	14,526	20,667	25,523	28,182	30,206	31,821	34,265	36,332	41,280	42,955	44,718	46,628
	137	Utility Terrace	888	1,600	4,597	6,104	8,119	9,587	11,305	12,650	13,972	16,786	19,094	23,219	25,451	27,462	29,685
	138	post-1985 Terrace	740	1,870	9,126	15,629	21,729	27,978	30,630	32,579	33,957	36,295	38,304	42,997	44,432	46,077	47,747
Bungalow	141	pre-1919 Bungalow	1,817	3,691	14,297	22,104	30,984	38,104	42,274	45,003	47,109	50,944	53,983	60,332	63,248	65,836	68,853
	142	1919-1944 Bungalow	1,727	5,161	21,427	31,915	42,730	50,981	56,211	60,477	64,579	70,527	75,734	85,494	90,778	96,134	102,388
	143	1945-1964 Bungalow	1,760	4,295	18,994	29,077	39,558	47,054	52,004	56,078	59,804	66,595	73,092	83,802	90,336	96,697	104,911
	144	1965-1974 Bungalow	1,569	5,475	22,357	33,221	44,500	51,751	57,418	62,575	67,421	75,336	82,105	93,021	99,508	105,357	112,808
	145	1975-1985 Bungalow	1,388	4,036	17,263	26,391	36,779	43,735	49,647	54,355	57,934	64,447	69,882	79,101	83,242	86,291	90,151
	148	post 1985 Bungalow	1,359	3,806	18,136	29,174	39,530	49,731	55,795	60,420	63,577	69,965	75,391	84,127	87,871	90,793	94,246
Flat	151	pre-1919 Flat	1,652	2,982	10,185	16,975	23,194	28,404	30,688	32,546	33,943	35,482	37,161	41,095	42,576	44,222	46,394
	152	1919-1944 Flat	1,399	4,181	18,377	27,895	37,266	44,115	47,891	51,123	53,888	56,848	59,793	65,909	68,508	71,196	74,714
	153	1945-1964 Flat	1,039	2,370	9,657	15,677	22,131	27,384	29,791	31,535	33,075	35,146	37,287	41,530	43,317	44,818	46,670
	154	1965-1974 Flat	890	3,486	14,784	22,347	29,988	35,346	38,909	41,986	44,477	47,431	50,482	56,863	59,552	62,517	66,251
	155	1975-1985 Flat	746	2,151	9,943	16,441	23,345	28,544	31,836	34,071	35,624	37,649	39,567	44,674	46,021	47,381	49,060
	157	utility Flat	875	1,423	3,936	5,466	7,303	8,658	10,308	11,540	12,760	15,274	17,539	21,339	23,579	25,574	27,785
	158	post 1985 Flat	691	1,893	10,087	17,522	24,369	31,178	34,458	36,602	37,880	39,776	41,624	46,431	47,502	48,723	50,126

Figure 1.1: Example of MCM's Depth Damage Data for Residential Properties

2 RECORDING DAMAGE ASSESSMENT DATA

Damage assessments are carried out in order to quantify the economic risk to the study area. This requires many details to be recorded such as background data, interim calculations and final damage results. RPS creates geo-referenced shapefiles with relevant data recorded in their attribute tables, an example of which is shown in Figure 2.1. Each flood mechanism to be assessed requires a building polygon shapefile and a damage assessment point file.

Building polygon shapefiles are created to contain background data for building polygons including building use and area. These commonly originate from datasets provided by the relevant local authority.

Damage assessment point files are created to contain all information needed to complete the damage assessment. Information such as building area, finished floor level (FFL) and water elevations extracted from the modelled flood events are combined into this shapefile to give flood depths referenced to finished floor level for each simulated event. For buildings with multiple water elevation entries, the maximum level of water above FFL is taken. These shapefiles are used to display economic risk of properties relating to a range of flood events.

The following sections detail how damage assessments are carried out and the data that is recorded during various processes.

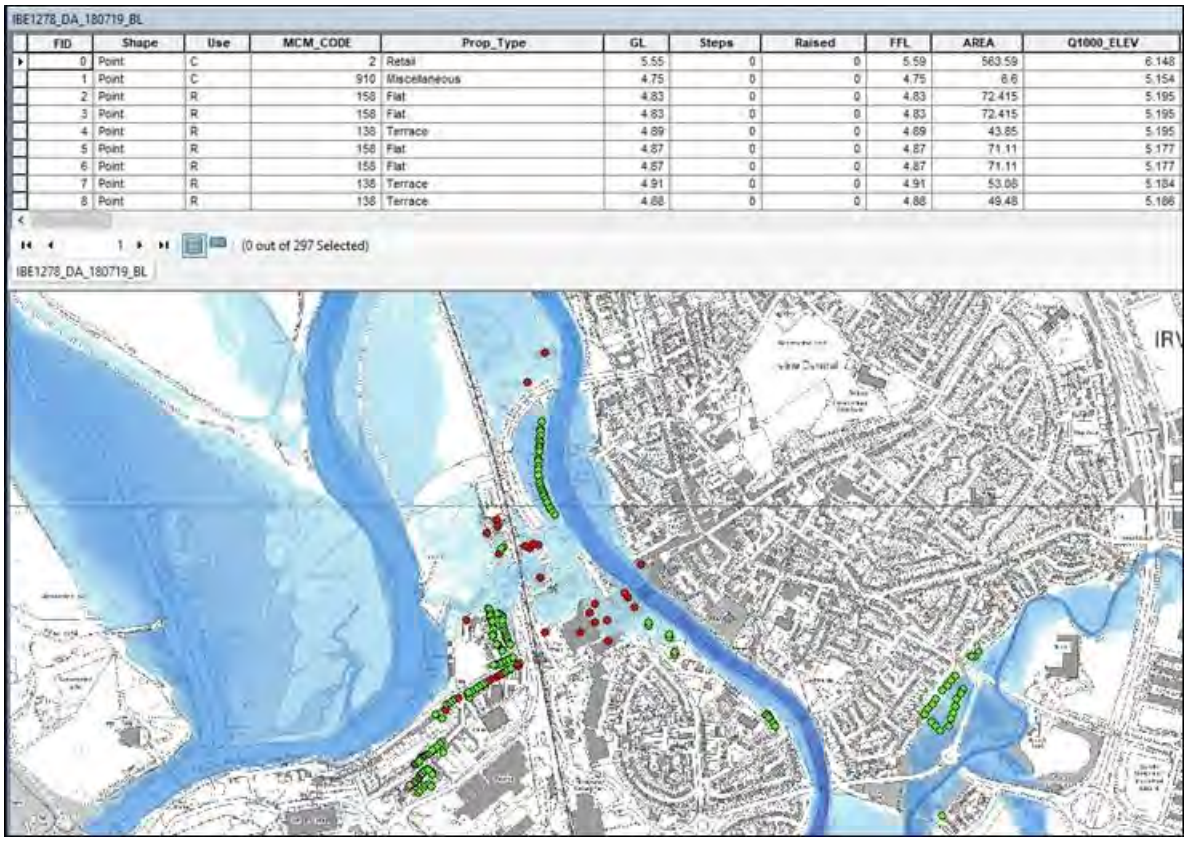


Figure 2.1: Example Damage Assessment Property Shapefile with Attributes Showing Damage Assessment Data

3 CATEGORISATION OF PROPERTIES

All properties within the largest modelled floodplain/s are surveyed and classified according to MCM guidelines. Based on the level of assessment, the following attributes may be recorded for residential properties; property type, age and social class. Social class data is provided in the MCM based on social classes AB, C1, C2 and DE based on England and Wales. As social class data is not collated under the same categories and methodology in Scotland as in England and Wales, these cannot be made comparable. As such, social class is not considered in economic damage assessments in Scotland.

The MCM assigns a code to each property type to aid the damage calculations. Table 3.1 and Table 3.2 detail the various residential and non-residential property types.

Table 3.1: Residential Properties MCM Codes

Property Type	MCM code	Property Type - Age
Detached	111	Pre-1919 Detached
	112	1919-1944 Detached
	113	1945-1964 Detached
	114	1965-1974 Detached
	115	1975-1985 Detached
	117	Utility Detached
	118	Post-1985 Detached
Semi-Detached	121	Pre-1919 Semi-Detached
	122	1919-1944 Semi-Detached
	123	1945-1964 Semi-Detached
	124	1965-1974 Semi-Detached
	125	1975-1985 Semi-Detached
	127	Utility Semi-Detached
	128	Post-1985 Semi-Detached
Terrace	131	Pre-1919 Terrace
	132	1919-1944 Terrace
	133	1945-1964 Terrace
	134	1965-1974 Terrace
	135	1975-1985 Terrace
	137	Utility Terrace
	138	Post-1985 Terrace
Bungalow	141	Pre-1919 Bungalow
	142	1919-1944 Bungalow
	143	1945-1964 Bungalow
	144	1965-1974 Bungalow
	145	1975-1985 Bungalow
	148	Post 1985 Bungalow
Flat	151	Pre-1919 Flat
	152	1919-1944 Flat
	153	1945-1964 Flat

Property Type	MCM code	Property Type - Age
	154	1965-1974 Flat
	155	1975-1985 Flat
	157	Utility Flat
	158	Post 1985 Flat

Table 3.2: Non-Residential Property MCM Codes

MCM CODE	PROPERTY TYPE
2	Retail
3	Offices
4	Warehouses
5	Leisure and Sport
51	Leisure
52	Sport
521	Playing Field
523	Sports Centre
526	Marina
525	Sports Stadium
6	Public Buildings
8	Industry
9	Miscellaneous
910	Car park
960	Sub-Station

Depth damage data is not provided for garages and sheds in the MCM. Properties classified as garages, sheds, or other buildings which will not incur damage are classified with the MCM code -999, and are screened out prior to the next stage in the assessment.

The following categorisation details are recorded for each building within the largest modelled flood extent:

Table 3.3: Categorisation of Properties Data

Data Type	Attribute Name	Data Details
Property Use	Use	"R" for residential and "C" for commercial
MCM Code	MCM_CODE	As per MCM guidelines
Property Type	Prop_Type	As per MCM guidelines
Floor Area	Area	Floor area of the property

4 PROPERTY THRESHOLD LEVEL

The damage assigned to a property relates to the depth of water above floor level. As such the threshold level of all properties is required as part of the damage assessment. As a general rule most properties are constructed with the floor level raised 300mm above the adjacent ground level. This would be particularly characteristic of fluvial or coastal floodplains which are generally low lying and flat in nature. Steep topography also has an influence on finished floor levels whereby some properties have split level front doors and back doors and some properties enter at ground level but have basements below.

Where a finished flood level (FFL) survey has been carried out, FFLs are directly transposed into the damage assessment shapefile/s. These are considered the most accurate method of providing FFLs. RPS ensure that any FFL surveys which are carried out specify the surveyor to use a total station, to avoid errors induced by differential GPS stations being used close to buildings which reduced the accuracy due to disturbing clear lines of site to GPS satellites. In the occurrence of multiple entrances to a property being surveyed, a conservative threshold is chosen based on the lowest level surveyed for the FFL.

In absence of FFL surveys, RPS calculate the average level from LiDAR across the building footprint to provide a ground level. A survey of steps into the property allows the height the FFL is raised to be estimated. Each step is counted as +150mm above LiDAR defined ground level. For example if there are two steps the raised height above ground level would be 300mm. Table 4.1 shows the details recorded in the damage assessment shapefile. A number of QA checks are carried out to ensure damages are not over / underestimated, with any manual updates recorded in the attribute tables of the shapefile.

Table 4.1: Property Threshold Data

Data type	Attribute name	Data details
Ground Level	GL	LiDAR data extracted at each property, measured in mOD Newlyn. Where an FFL survey is available, a null value of -999 is recorded.
How many steps into property	Steps	Number of steps into property entrance. Where details of property entry are unknown “-999” value recorded.
Is ground floor raised	Raised	Calculated from “Steps” column. Each step to be 0.15m, on basis of 0.3 standard entry to residential properties. Where “-999” value recorded the 0.3m standard entry is assumed for residential properties and 0m for non-residential properties.
Finished Floor Level	FFL	GL + Raised = FFL. For properties with basements FFL is calculated to be ground level minus 2.5m.

5 FLOOD DEPTH OF PROPERTIES

To estimate the damage to a property, estimations of predicted flood depths are required for a wide range of flood events. The depths to which properties in the assessment are flooded are calculated for modelled events prescribed in the brief; for Scottish assessments the events prescribed are commonly 1 in 2, 1 in 5, 1 in 10, 1 in 30, 1 in 50, 1 in 100, 1 in 200 and 1 in 1000.

The depth of flooding is calculated by finding the difference between the flood water elevation and the estimated threshold level. The flood elevations are extracted from the hydraulic model outputs to find the maximum depth of water touching each building polygon for each event. This process is achieved by carrying out a statistical analysis in ArcGIS. Table 5.1 below shows details which are recorded within the attribute tables of the damage assessment shapefile:

Table 5.1: Flood Depth of Properties Data

Data type	Attribute name	Data details
Flood level for all flood events	Q1000_ELEV, Q200_ELEV, Q100_ELEV, Q50_ELEV, Q30_ELEV, Q10_ELEV, Q5_ELEV, Q2_ELEV.	The maximum flood level adjacent to the building (mOD).
Flood depth for all flood events	Q1000_Dp, Q200_Dp, Q100_Dp, Q50_Dp, Q30_Dp, Q10_Dp, Q5_Dp, Q2_Dp.	Difference between the flood level and FFL.

6 FLOOD DAMAGE TO PROPERTIES

Once the depths of flooding are known the damage can be calculated using the MCM depth damage data. This is known as direct damage in that the flooding directly damages assets; it does not account for indirect damages such as heating costs to dry out the house. For each property type, a typical damage based on historical data has been assigned to a depth of flooding. The latest version of the MCM data is sourced, where the damage per square metre of the floor area of a building is used. This assessment adopted the fluvial depth damage data. A sensitivity analysis was also carried out using the sewage depth damage data, which has been discussed further in Section 15.

The direct damage in each flood event for each building in pounds sterling prices per square metre is calculated by interpolating between the depth damage figures provided in the MCM guidance. This damage figure is then multiplied by the floor area of the property to give the total damage. This information is recorded in the attributes listed in Table 6.1.

Table 6.1: Flood Damage to Properties Data

Data type	Attribute name	Data details
Direct damage per meter square	Q1000_M2Dm, Q200_M2Dm, Q100_M2Dm, Q50_M2Dm, Q30_M2Dm, Q10_M2Dm, Q5_M2Dm, Q2_M2Dm.	Damage per meter square to each property according to the depth of flooding from each flood event as per MCM data.
Principal Direct Damage (PDD) - Damage to property over full floor area	Q1000_PDD, Q200_PDD, Q100_PDD, Q50_PDD, Q30_PDD, Q10_PDD, Q5_PDD, Q2_PDD.	Damage per meter square multiplied by floor area of building.

7 INDIRECT COSTS

Indirect costs account for tangible costs incurred that are not included in the direct damages. The MCM provides damage data for a range of indirect costs, which are considered at different economic levels of analysis. The Langholm Flood Protection Scheme considered the following indirect costs; emergency, utility and evacuation costs. An additional sensitivity analysis was carried out to account for electricity costs associated with dehumidification equipment commonly used to assist in dying-out a property after it has been flooded. This has been discussed further in Section 15.

7.1 Evacuation Costs

Where a damage to a property has occurred due to flooding, evacuation from the property may be necessary to allow any damage to be repaired. Research into previous flood events found the evacuation costs comprised a significant proportion of the costs relating to flooding, therefore a methodology was developed to allow this to be considered in economic assessments.

For an initial level of analysis, the MCM provides indicative costs, based on the depth of flooding inside the property and the property type. Based on the depth inside the property the MCM has attributed indicative durations, which were also considered in the evacuation costs provided.

The MCM provides data for three different damage levels; high, mid / indicative and low. RPS adopted the evacuation costs provided from the mid / indicative category, as to avoid over or under estimation of damages and subsequent benefits derived from flood alleviation measures. The evacuation costs in the MCM are presented in Figure 7.1

MAXIMUM DEPTH INSIDE PROPERTY (CM)	EVACUATION COSTS BY PROPERTY TYPE (£)											
	DETACHED			SEMI-DETACHED			TERRACED			FLAT		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
0-1	681	1,007	1,631	609	865	1,419	588	838	1,387	532	782	1,330
1-10	1,308	1,928	3,126	1,169	1,653	2,714	1,126	1,600	2,652	1,018	1,491	2,540
10-20	2,511	3,662	5,954	2,232	3,108	5,126	2,146	3,002	5,001	1,928	2,781	4,776
20-30	2,694	3,928	6,387	2,394	3,334	5,499	2,302	3,221	5,364	2,069	2,984	5,123
30-60	3,625	5,269	8,575	3,216	4,458	7,363	3,090	4,303	7,179	2,772	3,980	6,850
60-100	4,342	6,299	10,256	3,848	5,320	8,793	3,696	5,134	8,572	3,312	4,744	8,175
100+	6,965	10,045	16,383	6,154	8,438	13,981	5,905	8,132	13,617	5,275	7,491	12,965

Figure 7.1: MCM Evacuation Cost Data by Property

Evacuation costs were allocated to residential properties based on the flood depth relative to the finished floor level. These figures were input into the MCM evacuation costs data and a cost per property per event was calculated.

Table 7.1: Evacuation Cost Data

Data type	Attribute name	Data details
Indirect Costs	Q1000_Evac, Q200_Evac, Q100_Evac, Q50_Evac,	Cost based on MCM evacuation cost data set as function of depth.

Data type	Attribute name	Data details
	Q30_Evac, Q10_Evac, Q5_Evac, Q2_Evac.	

7.2 Emergency Costs

A cost will be associated with emergency services dealing with the flood events. Following the Environment Agency's Flood or Coastal Erosion Risk Management (FCERM) appraisal guidance, which the MCM guidance has been adapted to comply with, a value of 10.7% of the principal direct damages is assigned to the emergency services costs. This figure is based on data collected from previous flood events in the UK.

An economic damage will also be incurred in flood events relating to infrastructure utility assets. Examples of these may include electrical sub-stations and telecommunications assets. A utility damage of 20% of the principal direct damage is applied to account for these impacts, based on the analysis of damages from historical flooding in the UK.

The details in Table 7.2 are recorded within the economic risk shapefile attribute tables:

Table 7.2: Emergency and Utility Cost Data

Data type	Attribute name	Data details
Emergency costs	Q1000_Emerg, Q200_Emerg, Q100_Emerg, Q50_Emerg, Q30_Emerg, Q10_Emerg, Q5_Emerg, Q2_Emerg.	Equal to 10.7% of the Principal Direct Damages (PDD).
Utility costs	Q1000_Util, Q200_Util, Q100_Util, Q50_Util, Q30_Util, Q10_Util, Q5_Util, Q2_Util.	Equal to 20% of the PDD.

8 EVENT DATA

The event damage is defined as the total of the direct damages in any one event, calculated to be the sum of the principal direct damage (PDD) to properties, emergency damages and utility damages. The event damage is required for later steps in the process, specifically in calculating annual average and present value damages. The event damage is recorded in the damage assessment shapefile as shown in Table 8.1.

Table 8.1: Event Damage Data

Data type	Attribute name	Data details
Event Damage	Q1000_EvDam, Q200_EvDam, Q100_EvDam, Q50_EvDam, Q30_EvDam, Q10_EvDam, Q5_EvDam, Q2_EvDam.	Summed direct damage of any one event. This is the total of the PDD, utility damage and emergency costs.

9 ANNUAL AVERAGE DAMAGE AND PRESENT VALUE DAMAGE

In order to gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying this as a percentage to the damage; this is known as the Annual Average Damage (AAD). The AAD can then be taken over the lifetime of the study that has been set at 100 years and discounted back to present day costs; this is known as the present value damage (PVD).

The AAD can best be described by considering the graph shown in Figure 9.1. The points shown represent the various design flood events where the event damage is calculated. Their position on the graph is dictated by the damage caused and the frequency of the flood event occurring in any given year. These points are joined together to create a damage curve. The area under the curve is therefore a function of the damage and the frequency and gives the AAD.

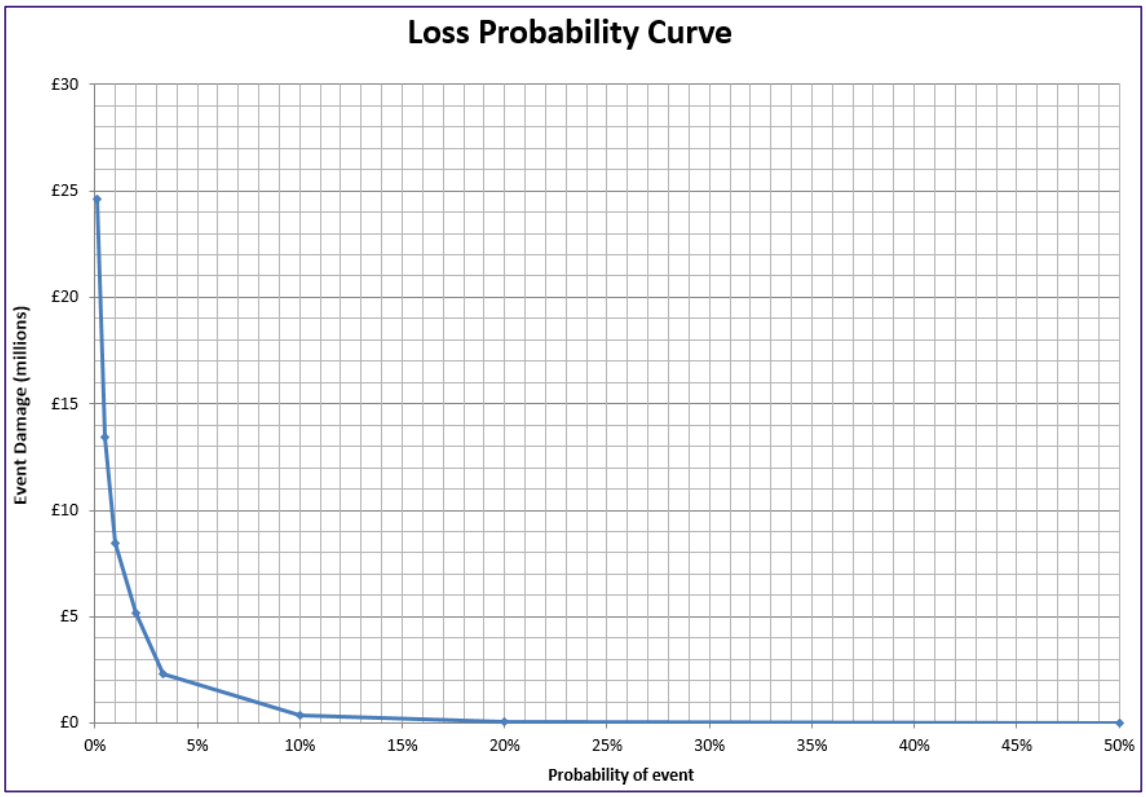


Figure 9.1: Loss Probability Curve for Langholm

Once the AAD is calculated the present value damage can be determined. The present value damage calculation sums the AAD that is expected to occur for each of the 100 years considered in Scottish studies. In order for the damage value in each year to be comparable with each other they are discounted to represent the equivalent present damage value. Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present day values. Discount rates are taken from the Treasury's 'Green Book' (HM Treasury, 2018), as shown in Table 9.1.

Table 9.1: The Green Book's Long Term Discount Rate

Period of Years	0 - 30	31 - 75	76 - 125
Discount Rate	3.5%	3.0%	2.5%

This results in factoring the AAD by 29.813. The AAD and PvD are calculated for the direct damages. Table 9.2 outlines the details that are recorded within the damage assessment shapefile attribute tables:

Table 9.2: AAD and PVD Data

Data type	Attribute name	Data details
Annual Average Damage for direct damages, intangible damages	AAD	The equation to calculate the AAD is as follows: (([Q2_EvDam]+[Q5_EvDam])/2*(0.5-0.2)+ ([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+ ([Q10_EvDam]+[Q30_EvDam])/2*(0.1-0.03333)+ ([Q30_EvDam]+[Q50_EvDam])/2*(0.03333-0.02)+ ([Q50_EvDam]+[Q100_EvDam])/2*(0.02-0.01)+ ([Q100_EvDam]+[Q200_EvDam])/2*(0.01-0.005)+ ([Q200_EvDam]+[Q1000_EvDam])/2*(0.005-0.001))
Present value damage	PvD	The AAD factored by 29.813.

10 CAPPING DAMAGES

It is recognised that for certain properties the overall damage associated with it can far exceed the market value of the property. This can be due to either the depth to which it floods or the frequency with which it floods or a combination of both factors. Where such a situation occurs it is necessary to cap the damages at the market value.

When capping damages for residential properties, the regional average risk free market value is used. Detailed research is carried out in order to establish an accurate and robust representation of property values for the study area.

For a non-residential property its capping value is calculated by its rateable value multiplied by a factor which reflects the added value of percentage rental yield from that property is used. The methods used to acquire robust values for capping damages are recommended in the FCERM Manual 2013 and the MCM 2016. Research is carried out to identify both the rateable value and the average rental yield for commercial properties in the region. For percentage rental yield, an average for Scotland of around 6% is identified using data produced by Savills, 2017, therefore using MCM guidance a multiplier of 16.7 would be appropriate.

The approach taken by RPS, in line with MCM guidance, is to cap the direct damages and to leave the intangible flood impacts uncapped before totalling up the overall damages. This process is outlined in Section 14.

The following details in Table 10.1 and Table 10.2 are incorporated within damage assessment shapefile attribute tables:

Table 10.1: Commercial Capping Damages Data

MCM_Code	Property Type	Capping Value /m^2
2	Shops	£140.87 x 16.7 = £2,352.53
3	Offices	£97.52 x 16.7 = £1,628.58
4	Warehouses	£36.26 x 16.7 = £605.54

MCM_Code	Property Type	Capping Value /m^2
5	Leisure & Sport	£58.76 x 16.7 = £981.29
51	Leisure	
52	Sport	
521	Playing Field	
523	Sports Centre	
525	Sports Stadium	
526	Marina	
9	Miscellaneous	
910	Car park	
960	Substation	
6	Public Buildings	£58.76 x 16.7 = £981.29
8	Industry	£28.76 x 16.7 = £480.29

Table 10.2: Capping Damages Data

Data type	Attribute name	Data details
Capped direct damages (baseline scenario)	PvD_BL_Cap	Residential property damages over capping value are set equal to this value. Commercial property damages capping value = rateable value x % rental yield.
Capped direct damages (defended scenario)	PvD_Df_Cap	The direct damages in the defended scenario are also capped using the same capping data for the baseline.

11 INTANGIBLE IMPACTS OF FLOODING

Apart from the material damages to the building structure and the goods inside the property, it is recognised that there are monetary damages associated with stress, health effects and loss of memorabilia, which can be as important as direct material damage to householders. The MCM guidance assesses these impacts as intangible benefits that are associated with flood defence improvements. For analysis of intangible benefits Defra's risk reduction matrix is commonly used (Defra, 2004), as shown in Table 11.1. The calculated intangible benefits are summed with the benefits derived from direct damage avoided to provide the total benefit; this is discussed in more detail later. In line with the Defra methodology, the intangible benefit is not capped.

Table 11.1: Intangible benefits associated with flood risk management improvements (2018/19 prices) (FRHC, 2018)

Standard of Protection After – AFP (RP in years)										
Standard of protection before – AFP (RP in years)			0.007	0.008	0.01	0.013	0.02	0.033	0.05	0.1
			-150	-125	-100	-75	-50	-30	-20	-10
	1	-1	£297	£293	£273	£208	£100	£34	£16	£6
	0.1	-10	£292	£286	£266	£202	£92	£29	£11	£0
	0.05	-20	£280	£275	£256	£192	£82	£18	£0	-
	0.033	-30	£263	£257	£238	£174	£64	£0	-	-
	0.02	-50	£197	£193	£173	£109	£0	-	-	-
	0.013	-75	£89	£85	£64	£0	-	-	-	-
	0.01	-100	£25	£20	£0	-	-	-	-	-
	0.008	-125	£5	£0	-	-	-	-	-	-

AFP = Annual Flood Probability
RP = Return Period
Annual Benefits = Damages (before) - Damages (after)

No intangible damages are assigned to commercial properties as these costs do not apply at the same level.

12 VEHICLE DAMAGE

Research for the MCM ascertained an average value for a typical motor vehicle in the UK to be £3,100. It is also stated that vehicles are most likely to be damaged and written off at a flood depth of 0.35m (above ground level). The MCM also states that the average number of cars per household is 1.16, based on Department for Transportation research carried out in 2011. Combining the average motor vehicle cost and number of cars per household provides a vehicle cost of £3,600, when the flood depth from ground level exceeds 0.35m. The vehicle costs were calculated for residential properties, annualised and converted to present value costs. In line with MCM guidance neither the damages nor benefits are capped. The present value damages and benefits associated with flood alleviation measures were incorporated into the final PvD and PvB for the project.

13 DAMAGE ASSESSMENT REVIEW

A review of damage assessments are carried out to quality check the data being used. Some basic checks carried out by the damage assessors include reviewing the properties that contribute over 1% of the capped PvD, checking the area and thresholds of large commercial buildings and spot checking depth damage data is correctly applied. Checks are also carried out by the modeller, to ensure the model is calibrated to historic events and to inform the optioneering process.

A quality assurance spreadsheet has been developed by RPS to ensure a number of checks are carried out throughout the process, which is included as part of the appendices of any flood risk study which includes a damage assessment.

14 CALCULATION OF TOTAL BENEFIT

The total economic benefit for study areas are calculated as the sum of the direct and intangible benefits. Damages are assessed up the 0.1% AEP, protecting all properties in the assessment within the 0.5%CC AEP extent. As damages for the 0.5%CC AEP cannot be reasonably estimated without of full suite of climate change model runs, there will be a residual damage in the study area where properties are not protected above the 0.5% AEP event (excluding climate change). To be conservative the benefit is derived based on providing the 0.5% AEP without climate change. The intangible benefit is uncapped as discussed previously. The relevant fields in the economic risk shapefile are provided in Table 14.1.

Table 14.1: Benefits and Related Fields in the Economic Damage Assessment

Data Type	Attribute Name	Data Details
Present value damage (PvD) in baseline scenario	PvD_BL	Damages assessed up to 0.1% AEP.
PvD in baseline scenario (capped)	PvD_BL_Cap	Any present value damage greater than CapVal is capped at the CapVal. Any damage less than the CapVal is let equal to the original present value damage.
PvD in defended scenario	PvD_Df	Residual damages with properties protected up to 0.5% AEP (only 0.1% AEP damages remain).
PvD in defended scenario (capped)	PvD_Df_Cap	Capping applied similar to PvD_BL_Cap.
Present value benefit (PvB) derived from direct damage avoided (capped)	PvB_Cap	Calculated by the following: PvD_BL_Cap - PvD_Df_Cap
PvB relating to intangible impacts avoided	PvB_Int	Derived from Defra Intangible Matrix. Intangible benefits are not capped.
Final PvB for the study area	PvB_Final	Calculated by the following: PvB_Cap + PvB_Int

15 SENSITIVITY ANALYSIS

A review of the RPS damage assessment methodology was undertaken by John Chatterton & Associates for the Langholm FPS, which provided comments which fed into the final version of the economic assessment completed for the study. Mr. Chatterton advised that a sensitivity analysis be carried out to determine how the benefit might be altered with regards to the following approaches:

- Sewage depth damage data be adopted in place of fluvial depth damage data;
- Addition of electricity costs, associated with the running of air blowers or de-humidifiers used to dry out properties post-flood.

The outcomes of the sensitivity analysis is provided in Table 15.1.

Table 15.1: Summary of Sensitivity Analysis

Assessment	Present Value Benefit	Additional Benefit	
		£	% increase
Final baseline benefit	£10,281,037.66	-	-
Sewage data used in place of fluvial data	£10,295,743.88	£14,706.22	+0.14%
Electricity damages applied	£10,341,905.08	£60,867.42	+0.59%

The results of the sensitivity analysis found the benefits to increase by less than 1% for both sensitivity scenarios. As the final baseline assessment was found to not be sensitive to the methodology changes assessed, and to provide a conservative approach, the baseline assessment was utilised for the project.

Appendix C

Classification of Properties & Depths of Flooding

(Shapefiles to be provided separately)

Appendix D

Long List of Actions

APPENDIX D

LONG LIST OF ACTIONS

Table 1 - Long List of Potential Actions

Action	Action Type	Description
Flood Protection Scheme (Do Nothing)	Accept	Maintain existing flood risk management practices and existing defences
Relocation	Avoid	Relocation of properties/infrastructure away from flood risk areas
National Planning Policies	Avoid	Scottish Planning Policy and Planning Advice Notes
Local Planning Policies	Avoid	Specific policies/guidance in local development plans in addition to National Planning Policy. Use of Strategic Flood Risk Assessment to inform local development plans
Runoff Reduction	Reduce/Protect (NFM)	Changing how the land is used in order to slow down surface water runoff. This may include woodland planting, creation/restoration of non-floodplain wetlands, agricultural and upland drainage modifications and land and soil management practices
Floodplain Storage	Reduce/Protect (NFM)	Increasing the storage of the floodplain. This may be done through; reach and floodplain restoration; floodplain and riparian woodlands; in stream structures; reach reinstatement; and offline storage and washlands
Sediment Management	Reduce/Protect (NFM)	Reduction in the deposition of sediment through reach restoration; sediment traps; and bank restoration
Storage	Reduce/Protect (Engineering)	Storage by dams, reservoirs, and offline washlands
Conveyance	Reduce/Protect (Engineering)	Improving the conveyance of the channel by; deepening of channel bed; widening of channel; realigning long section profile; routing the watercourse through culvert; removal of hydraulic constrictions; diverting the flow; or increasing the size of existing culverts
Control Structures	Reduce/Protect (Engineering)	Control flows by means of; sluice gates; penstock; flap valves; weirs; trash screens; or pumping stations
Direct Defences	Reduce/Protect (Engineering)	Protection using earth embankments; reinforced concrete walls; and demountable/temporary barriers.
Watercourse Maintenance	Reduce/Prepare	Increased frequency of routine maintenance, targeting of problem culverts, bridges or other control structures, removal of debris and rubbish tipping, desilting of sedimentation prone areas
Property Level Protection	Reduce/Prepare	Flood protection and resilience options such as flood gates, vent covers, use of flood resilient materials, raising electrical power points, etc.
Flood Forecasting & Warning	Reduce/Prepare	Installation of flood forecasting and warning system
Self Help	Reduce/Prepare	Informing public who live, work or use a flood risk area on the risks of flooding and how to prepare for flooding. Formation of Community Flood Action Groups
Emergency Plans	Reduce/Prepare	Development of emergency flood response procedures
Site Protection Plans	Reduce/Prepare	Development of single site flood protection plan for assets of regional or national importance

Action	Action Type	Description
Improved Understanding	Reduce/Prepare	Modelling and other assessments to improve the knowledge of flood hazards and impacts

Appendix E

Option Costs

Option Description Langholm

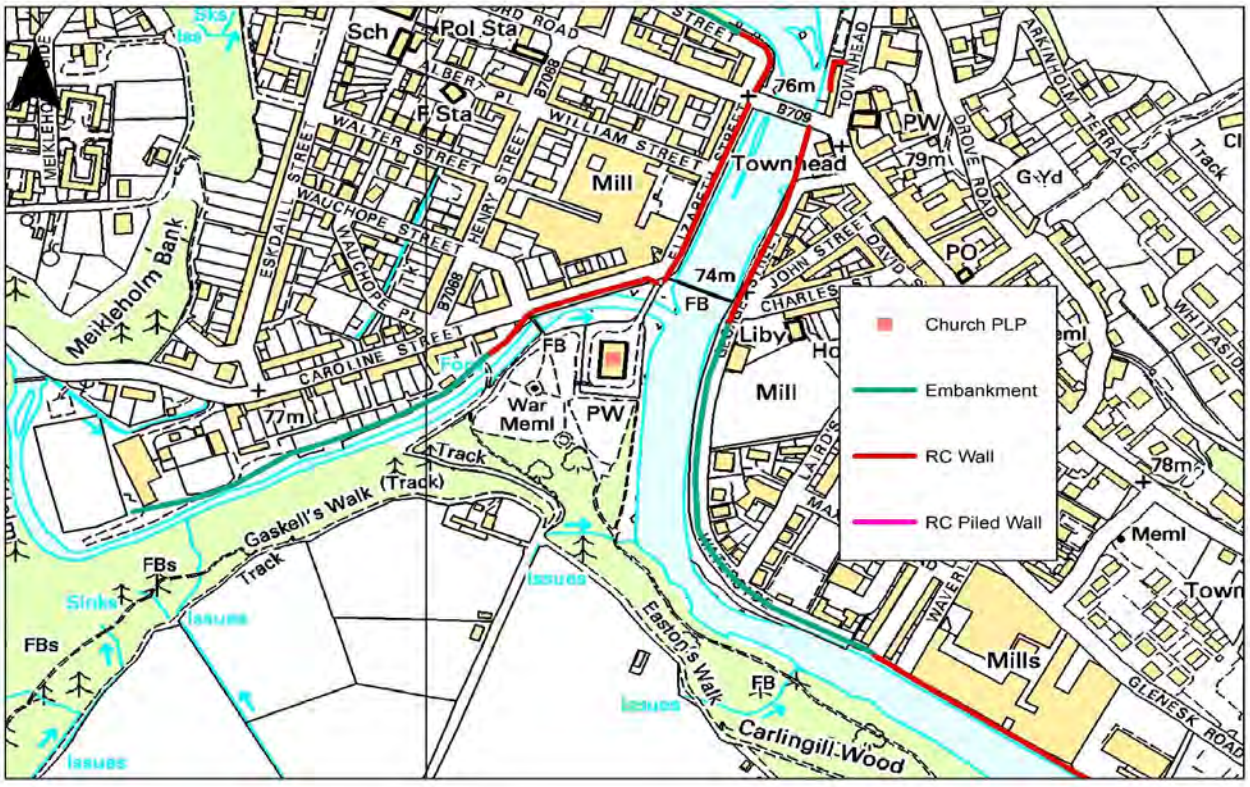
Option 1 - Direct Defences

Option 1 consists of 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 is provided to the Church of Scotland.

List of elements

1. Earth Embankment
2. RC Retaining Wall Type 1
3. RC Wall with Piled Base
4. RC Retaining Wall Type 2
5. PLP

Sketch of Option



Element 1 Construction Costs

Earth Embankment

Quantities generated from GIS modelling and a standard embankment cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Slope (1:X)	Cutoff depth	Crest width	CSA	Surface width	Footprint
1	49.95	1.51	2.5	0.75	1	8.00	9.16	852.07
2	49.70	1.70	2.5	0.75	1	9.67	10.15	884.60
3	49.47	1.38	2.5	0.75	1	6.89	8.43	817.17
4	48.82	1.27	2.5	0.75	1	6.05	7.84	785.08
5	49.95	1.40	2.5	0.75	1	7.05	8.54	829.14
6	40.96	1.48	2.5	0.75	1	7.71	8.97	693.10
7	58.82	1.24	2.5	0.75	1	5.83	7.68	938.80
8	50.00	0.72	2.5	0.75	1	2.77	4.88	694.00
9	37.46	1.10	2.5	0.75	1	4.88	6.92	576.87
10	50.10	1.40	2.5	0.75	1	7.05	8.54	831.58
11	49.11	1.69	2.5	0.75	1	9.56	10.09	871.82
12	49.22	1.70	2.5	0.75	1	9.68	10.15	876.04
13	50.31	1.98	2.5	0.75	1	12.53	11.66	951.87
14	50.32	2.00	2.5	0.75	1	12.75	11.77	955.99
15	47.68	2.00	2.5	0.75	1	12.75	11.77	905.94
16	46.30	1.11	2.5	0.75	1	4.96	6.99	715.46
17	33.74	1.63	2.5	0.75	1	9.02	9.78	591.17
18	22.14	4.20	2.5	0.75	1	49.05	23.62	615.38
19	17.06	2.26	2.5	0.75	1	15.74	13.15	341.75
20	24.42	2.55	2.5	0.75	1	19.56	14.73	517.70
21	31.16	2.12	2.5	0.75	1	14.15	12.44	607.54
22	23.95	1.55	2.5	0.75	1	8.31	9.35	412.02

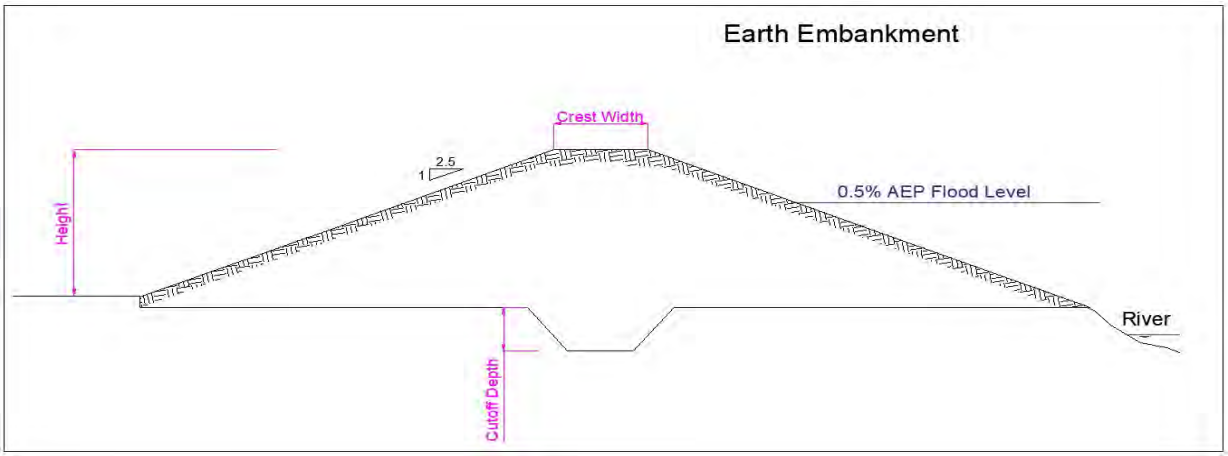
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	2	ha	£230	Prev. Job	£374
2.	Clearance - Site clearance & disposal	16265	m²	£5	Prev. Job	£81,325
3.	Excavation - Topsoil strip & stockpile	4880	m³	£3	Prev. Job	£14,639
4.	Excavation - Cutting	698	m³	£5	Prev. Job	£3,511
5.	Disposal - Cutting	698	m³	£26	Prev. Job	£17,896
6.	Filling - Provision of topsoil	2714	m³	£16	Prev. Job	£43,422
7.	Filling - Topsoil (300mm depth)	2714	m³	£9	Prev. Job	£23,068
8.	Filling - Provision of clay fill	9034	m³	£25	Prev. Job	£225,840
9.	Filling - Placing of clay fill	9034	m³	£9	Prev. Job	£76,786
10.	Geotextile mat	9046	m²	£3	Prev. Job	£27,139
11.	Finishing - Grassing out	16265	m²	£1	Prev. Job	£17,078
12.	Drainage	931	m	£35	Prev. Job	£32,572
					Total construction cost	**£563,650**

Verification of Cost - SEPA UCD Embankments

Embankment volume	Average Cost (£/m^3)	Total Construction Cost
5,000m³ - 15,000m³	65	£ 623,114

Sketch of Element



Element 2 Construction Costs

Reinforced Concrete Retaining Wall - Type 1

Quantities generated from GIS modelling and a standard flood wall cross sectional makeup (see sketch).
Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	25.44	1.67	0.4	0.4	2.07	307.02	0.87	0.83
2	19.79	1.10	0.4	0.4	1.50	227.58	0.64	0.60
3	50.31	1.28	0.4	0.4	1.68	587.76	0.71	0.67
4	50.41	1.78	0.4	0.4	2.18	614.01	0.91	0.87
5	50.11	2.01	0.4	0.4	2.41	621.87	1.00	0.96
6	28.89	1.88	0.4	0.4	2.28	354.74	0.95	0.91
7	16.39	1.32	0.4	0.4	1.72	192.03	0.73	0.69
8	49.53	1.49	0.4	0.4	1.89	589.12	0.80	0.76
9	50.75	1.55	0.4	0.4	1.95	606.61	0.82	0.78
10	49.94	2.03	0.4	0.4	2.43	620.74	1.01	0.97
11	50.79	2.03	0.4	0.4	2.43	631.38	1.01	0.97
12	22.16	1.60	0.4	0.4	2.00	265.98	0.84	0.80

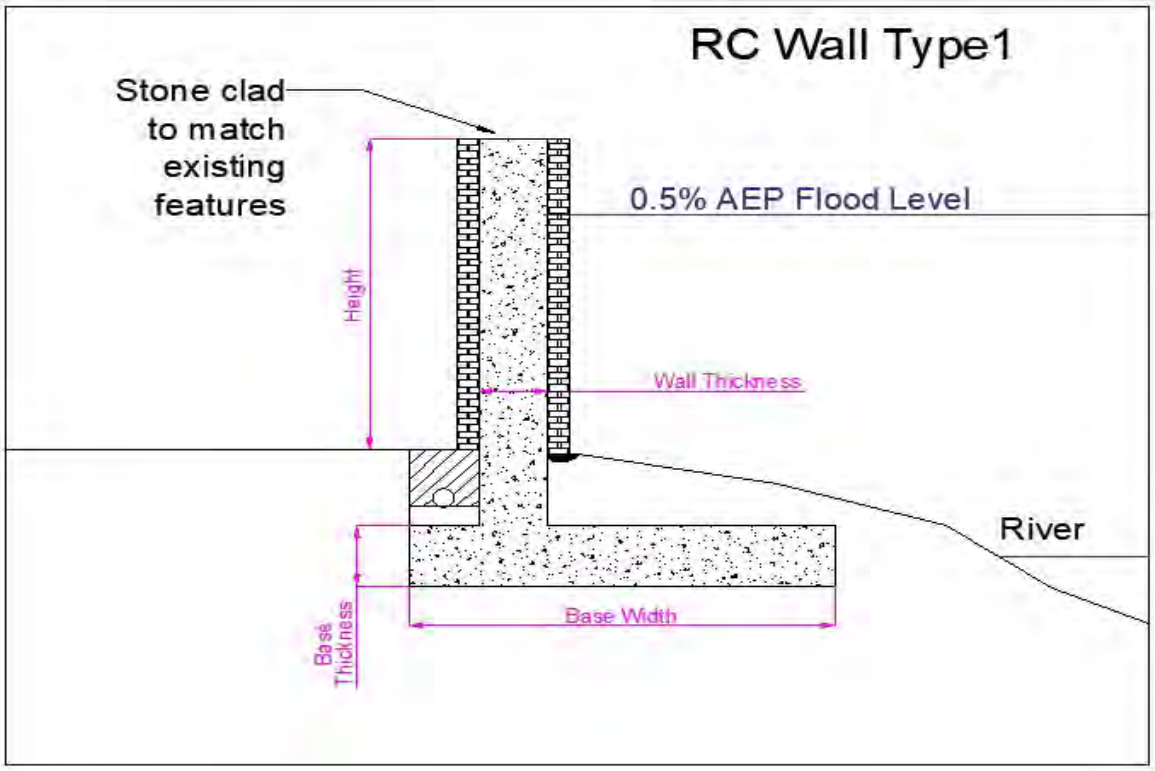
Cost Breakdown

Description	Quantity	Unit	Rate	Source	Total
1. Clearance - Vegetation killing	0.56	ha	£230	Prev. Job	£129
2. Clearance - Site clearance & disposal	5619	m²	£5	Prev. Job	£28,094
3. Excavation - Topsoil strip & stockpile	5619	m³	£3	Prev. Job	£16,857
4. Excavation - Cutting	665	m³	£5	Prev. Job	£3,345
5. Disposal - Cutting	665	m³	£26	Prev. Job	£17,052
6. Base Slab - Concrete	389	m³	£200	Prev. Job	£77,893
7. Base Slab - Reinforcement	31	t	£1,500	Prev. Job	£46,151
8. Base Slab - Trench fill	974	m³	£75	Prev. Job	£73,024
9. Base Slab - Formwork	372	m³	£110	Prev. Job	£40,878
10. Wall - Concrete	408	m³	£200	Prev. Job	£81,609
11. Wall - Reinforcement	32	t	£1,500	Prev. Job	£48,353
12. Wall - Formwork	2040	m²	£110	Prev. Job	£224,425
13. Wall - Finish (Granite)	1576	m²	£80	Prev. Job	£126,056
14. Drainage	465	m	£50	Prev. Job	£23,226
				Total construction cost	**£807,093**

Verification of Cost - SEPA UCD Flood Walls

Size	Average Cost (£/m)	Total Construction Cost
1.2 -2.1m	**2641**	**£ 1,226,750**
Size	**Upper Cost (£/m)**	**Total Construction Cost**
1.2 -2.1m	**4591**	**£ 2,132,602**

Sketch of Element



Element 3 Construction Costs

Reinforced Concrete & Pile Flood Wall

Quantities generated from GIS modelling and a standard flood wall with piled foundation cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	52.04	2.30	0.4	0.8	0.80	562.02	1.12	0.64
2	50.59	2.22	0.4	0.8	0.80	546.34	1.09	0.64
3	49.95	2.00	0.4	0.8	0.80	539.49	1.00	0.64
4	48.96	2.00	0.4	0.8	0.80	528.78	1.00	0.64
5	51.10	2.27	0.4	0.8	0.80	551.83	1.11	0.64
6	49.78	1.84	0.4	0.8	0.80	537.57	0.94	0.64
7	52.41	1.69	0.4	0.8	0.80	565.98	0.88	0.64
8	46.96	1.47	0.4	0.8	0.80	507.21	0.79	0.64
9	51.00	1.20	0.4	0.8	0.80	550.84	0.68	0.64
10	49.63	1.26	0.4	0.8	0.80	536.02	0.70	0.64
11	46.30	1.20	0.4	0.8	0.80	500.06	0.68	0.64

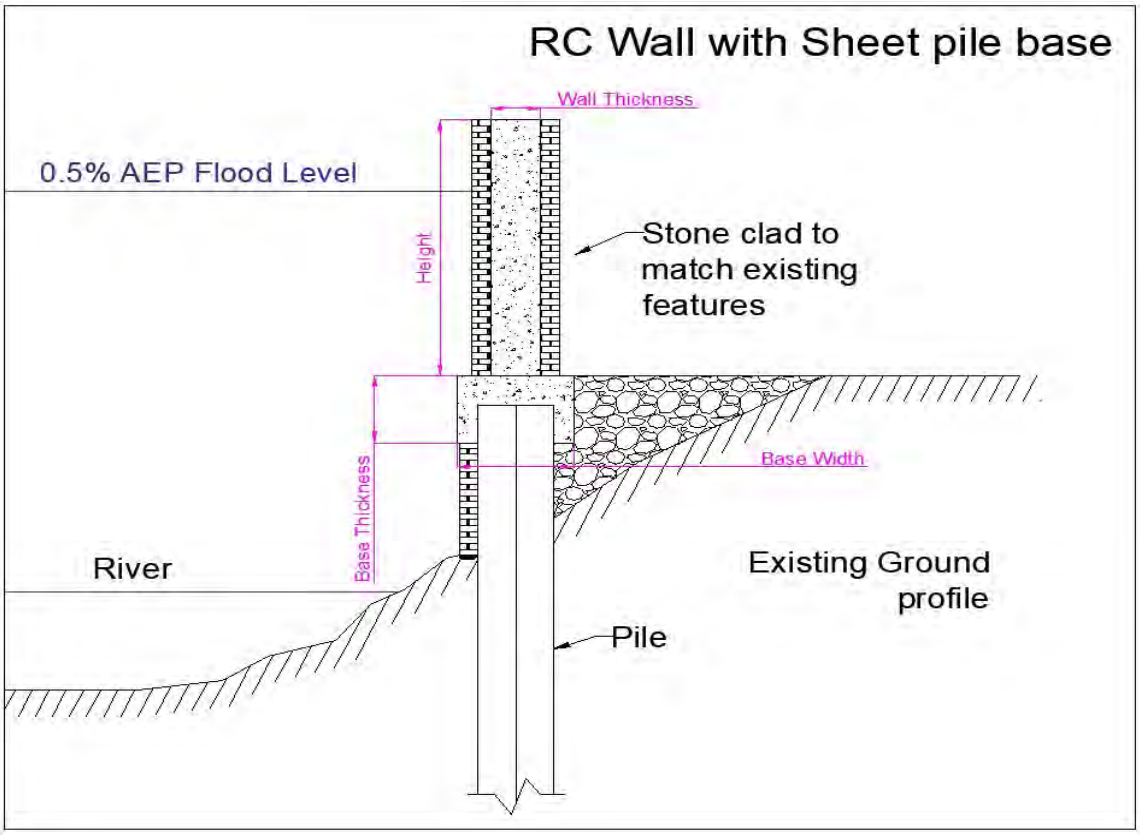
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.593	ha	£230	Prev. Job	£136
2.	Clearance - Site clearance & disposal	5926	m²	£5	Prev. Job	£29,631
3.	Excavation - Topsoil strip & stockpile	5926	m³	£3	Prev. Job	£17,778
4.	Excavation - Cutting	823	m³	£5	Prev. Job	£4,140
5.	Disposal - Cutting	823	m³	£26	Prev. Job	£21,104
6.	Base Slab - Concrete	432	m³	£200	Prev. Job	£86,313
7.	Base Slab - Reinforcement	28	t	£1,500	Prev. Job	£41,615
8.	Base Slab - Trench fill	439	m³	£75	Prev. Job	£32,923
9.	Base Slab - Formwork	878	m³	£110	Prev. Job	£96,574
10.	Wall - Concrete	999	m³	£200	Prev. Job	£199,819
11.	Wall - Reinforcement	39	t	£1,500	Prev. Job	£59,196
12.	Wall - Formwork	2498	m²	£110	Prev. Job	£274,752
13.	Pile - Provision & Placement	549	m	£1,893	Prev. Job	£1,038,446
14.	Wall - Finish (Granite)	1949	m²	£80	Prev. Job	£155,922
15.	Drainage	549	m	£50	Prev. Job	£27,436
					Total construction cost	**£2,085,786**

Verification of Cost - SEPA UCD Floodwall & Pile

Size	Average Wall Cost (£/m)	Construction Cost
1.2 -2.1m	**2390**	**£ 1,311,433**
Size	**Lower Pile Cost (£/m)**	**Construction Cost**
Length >100m	**1309**	**£ 718,270**
	Total:	**£ 2,029,703**

Sketch of Element



Element 4 Construction Costs

Reinforced Concrete Retaining Wall - Type 2

Quantities generated from GIS modelling and a standard retaining flood wall cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Protruding Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	50.00	1.80	1.30	0.4	0.4	0.33	516.50	0.92	0.13
2	50.00	2.88	1.58	0.4	0.4	0.86	542.90	1.35	0.34
3	100.00	3.71	1.81	0.4	0.4	1.25	1125.40	1.68	0.50
4	73.00	4.62	1.50	0.4	0.4	2.06	880.32	2.05	0.82

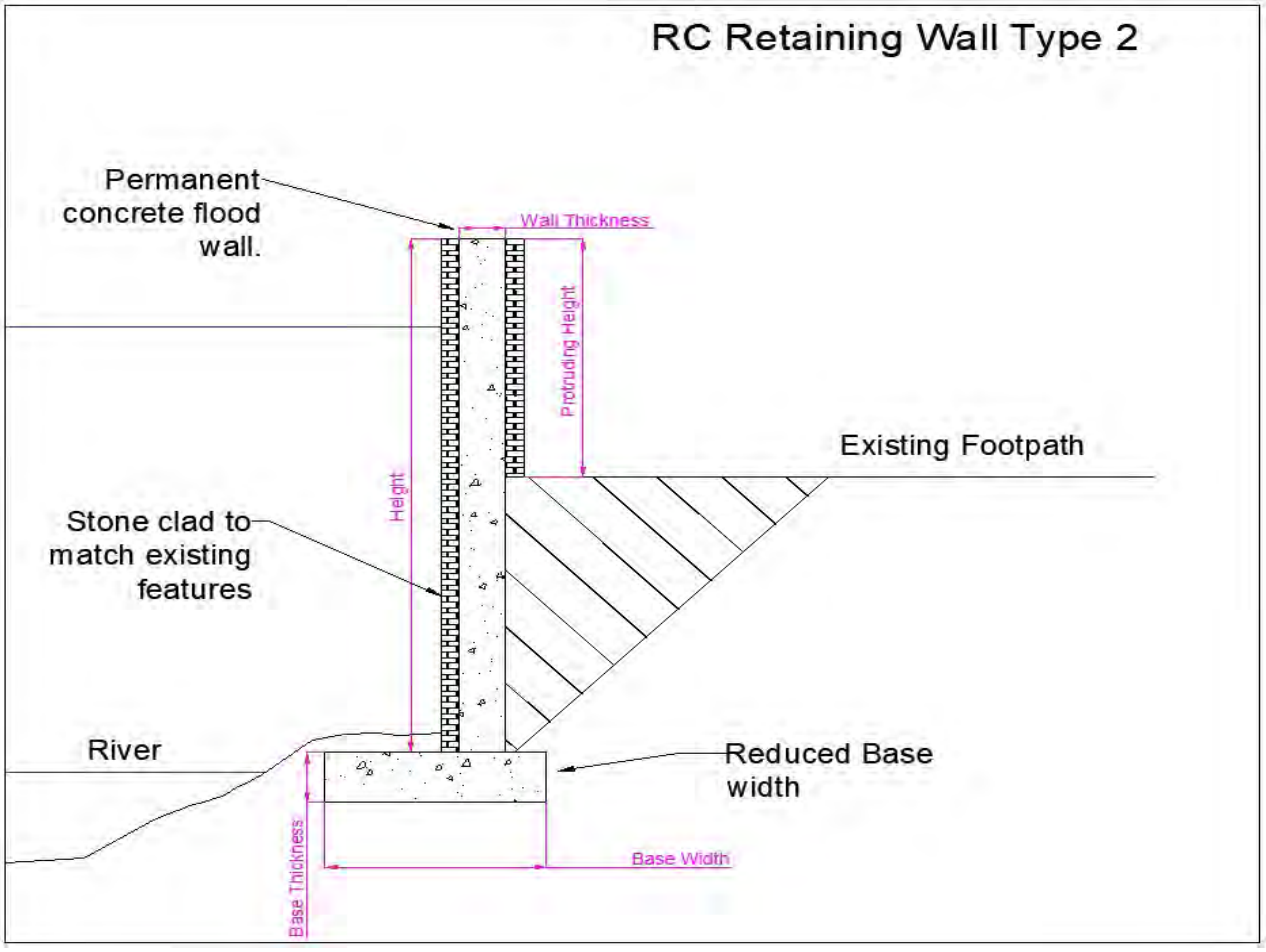
Cost Breakdown

	Description	Quantity	Unit	Rate	Source		Total
1.	Clearance - Vegetation killing	0.307	ha	£230	Prev. Job	£	70
2.	Clearance - Site clearance & disposal	3065	m²	£5	Prev. Job	£	15,326
3.	Excavation - Topsoil strip & stockpile	3065	m³	£3	Prev. Job	£	9,195
4.	Excavation - Cutting	215	m³	£5	Prev. Job	£	1,082
5.	Disposal - Cutting	215	m³	£26	Prev. Job	£	5,514
6.	Base Slab - Concrete	134	m³	£200	Prev. Job	£	26,810
7.	Base Slab - Reinforcement	11	t	£1,500	Prev. Job	£	15,885
8.	Base Slab - Trench fill	335	m³	£75	Prev. Job	£	25,134
9.	Base Slab - Formwork	218	m³	£110	Prev. Job	£	24,024
10.	Wall - Concrete	431	m³	£200	Prev. Job	£	86,281
11.	Wall - Reinforcement	34	t	£1,500	Prev. Job	£	51,121
12.	Wall - Formwork	2157	m²	£110	Prev. Job	£	237,272
13.	Wall - Finish (Granite)	1413	m²	£80	Prev. Job	£	113,041
14.	Drainage	273	m	£50	Prev. Job	£	13,650
					Total construction cost	**£**	**624,405**

Verification of Cost - SEPA UCD Flood Walls

Size	Average Cost (£/m)	Total Construction Cost
1.2 -2.1m	**2641**	**£ 720,968**

Sketch of Element



Element 5 Construction Costs

Property Level Protection

PLP costing estimates are taken from the SEPA Costing of Flood Rsk Management Measures (F4006), Category 4 - Resililence Measures. Note: For this costing, the church is estimated to be the equivelent of 3 detached properties.

SEPA UCD Flood Walls - Table 3.3 (£ per Property)

Category	Detached Property	Total Construction Cost	
Without floor - Upper	**32482**		**£ 97,446**

Enabling and Preliminary Costs

Preliminary costs include for work required before construction takes place. Examples include the setting up of the site compound area, surveys (structural, environmental, etc.), traffic management, provision of temporary access, watercourse management. A percentage of the construction costs is assumed as previous scheme have shown a relationship between the size of scheme's construction costs and the preliminary costs. A range of 10% - 30% is typical. The percentage assumed has also been based on factors such as the remoteness of the works, if there are known environmental and technical restrictions or whether it's in a heavily urbanised area.
Enabling costs cover items required before the construction and preliminary works can take place. This includes items such as professional fees, design, consultation, modelling, licence/planning fees. A percentage of the capital costs (construction + preliminary) is assumed as previous schemes have shown a relationship between the size of the scheme's capital costs and the enabling costs. Although each option comprises of multiple elements which may result in a specific enabling cost percentage the overall option has been considered when carrying out this estimation.

Preliminary Costs

Option Construction Costs	£	4,178,380
Preliminary Cost Percentage		10%
Preliminary Costs (£)	£	417,838
Assumptions	A lower estimate for preliminary costs has been used for this costing as the overall cost of the scheme is large.	

Enabling Costs

Option Capital Costs	£	4,596,218
Enabling Cost Percentage		10%
Enabling Costs (£)	£	459,622
Assumptions	The SEPA UCD indicates that the estimated enabling cost as a percentage of the scheme costs should range between 8 - 10 % for schemes > £1000k. Therefore a conservative value of 10% was used in costing this scheme.	

Operation and Maintenance

The various elements of this option will have associated operation and maintenance (O&M) costs. Costs are dependant on the responsible body (eg local authority, government body, private party), the complexity of the element (eg moving parts, high precision tolerances), and the robustness of the element (eg rate of degradation, risk of collapse).

Element 1 - Earth Embankment

Annual O&M cost	£	2,536
Assumptions	Cost based on a rate of £2,725/km/year. Maintenance includes for vegetation control, inspections, vermin control, back drainage improvements.	

Element 2 - RC Flood Wall

Annual O&M cost	£	262
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 3 - RC Flood Wall & Pile

Annual O&M cost	£	310
Assumptions	Cost based on a rate of £0.565 per m per annum for the RC wall & Pile. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 4 - RC Retaining Flood Wall

Annual O&M cost	£	113
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 5 - PLP

Annual O&M cost	£	1,949
Assumptions	Cost of maintenance based on paragraph 3.1.5 of SPA UC. Suggesting 2% of Capital Costs (£300-£900) per property per annum. = 0.02*97446 = £1949pa	

Total O&M Annual Costs

O&M costs per year	**£**	**5,170**

Whole Life Cost

Design Life

1. Earth Embankment 100yrs
2. RC Retaining Wall - Type 1 100yrs
3. RC Wall & Pile 100yrs
4. RC Retaining Wall - Type 2 100yrs
5. PLP 100yrs

Financial Assumptions

Financial period 100yrs

Discount rate 3.5% for year 0-30, 3% for year 31-75, 2.5% for year 76-99

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
0	1.000	877,460			877,460	-	-
1	0.966		4,178,380		-	4,037,082	-
2	0.934			5,170	-	-	4,827
3	0.902			5,170	-	-	4,663
4	0.871			5,170	-	-	4,506
5	0.842			5,170	-	-	4,353
6	0.814			5,170	-	-	4,206
7	0.786			5,170	-	-	4,064
8	0.759			5,170	-	-	3,927
9	0.734			5,170	-	-	3,794
10	0.709			5,170	-	-	3,665
11	0.685			5,170	-	-	3,541
12	0.662			5,170	-	-	3,422
13	0.639			5,170	-	-	3,306
14	0.618			5,170	-	-	3,194
15	0.597			5,170	-	-	3,086
16	0.577			5,170	-	-	2,982
17	0.557			5,170	-	-	2,881
18	0.538			5,170	-	-	2,784
19	0.520			5,170	-	-	2,689
20	0.503			5,170	-	-	2,598
21	0.486			5,170	-	-	2,511
22	0.469			5,170	-	-	2,426
23	0.453			5,170	-	-	2,344
24	0.438			5,170	-	-	2,264
25	0.423			5,170	-	-	2,188
26	0.409			5,170	-	-	2,114
27	0.395			5,170	-	-	2,042
28	0.382			5,170	-	-	1,973
29	0.369			5,170	-	-	1,907
30	0.356			5,170	-	-	1,842
31	0.346			5,170	-	-	1,788
32	0.336			5,170	-	-	1,736
33	0.326			5,170	-	-	1,686
34	0.317			5,170	-	-	1,637
35	0.307			5,170	-	-	1,589
36	0.298			5,170	-	-	1,543
37	0.290			5,170	-	-	1,498
38	0.281			5,170	-	-	1,454
39	0.273			5,170	-	-	1,412
40	0.265			5,170	-	-	1,371
41	0.257			5,170	-	-	1,331
42	0.250			5,170	-	-	1,292

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
43	0.243			5,170	-	-	1,254
44	0.236			5,170	-	-	1,218
45	0.229			5,170	-	-	1,182
46	0.222			5,170	-	-	1,148
47	0.216			5,170	-	-	1,115
48	0.209			5,170	-	-	1,082
49	0.203			5,170	-	-	1,051
50	0.197			5,170	-	-	1,020
51	0.192			5,170	-	-	990
52	0.186			5,170	-	-	961
53	0.181			5,170	-	-	933
54	0.175			5,170	-	-	906
55	0.170			5,170	-	-	880
56	0.165			5,170	-	-	854
57	0.160			5,170	-	-	829
58	0.156			5,170	-	-	805
59	0.151			5,170	-	-	782
60	0.147			5,170	-	-	759
61	0.143			5,170	-	-	737
62	0.138			5,170	-	-	715
63	0.134			5,170	-	-	695
64	0.130			5,170	-	-	674
65	0.127			5,170	-	-	655
66	0.123			5,170	-	-	636
67	0.119			5,170	-	-	617
68	0.116			5,170	-	-	599
69	0.112			5,170	-	-	582
70	0.109			5,170	-	-	565
71	0.106			5,170	-	-	548
72	0.103			5,170	-	-	532
73	0.100			5,170	-	-	517
74	0.097			5,170	-	-	502
75	0.094			5,170	-	-	487
76	0.092			5,170	-	-	475
77	0.090			5,170	-	-	464
78	0.087			5,170	-	-	452
79	0.085			5,170	-	-	441
80	0.083			5,170	-	-	431
81	0.081			5,170	-	-	420
82	0.079			5,170	-	-	410
83	0.077			5,170	-	-	400
84	0.075			5,170	-	-	390
85	0.074			5,170	-	-	381
86	0.072			5,170	-	-	371
87	0.070			5,170	-	-	362
88	0.068			5,170	-	-	353
89	0.067			5,170	-	-	345
90	0.065			5,170	-	-	336
91	0.063			5,170	-	-	328
92	0.062			5,170	-	-	320
93	0.060			5,170	-	-	312
94	0.059			5,170	-	-	305
95	0.057			5,170	-	-	297
96	0.056			5,170	-	-	290
97	0.055			5,170	-	-	283
98	0.053			5,170	-	-	276
99	0.052			5,170	-	-	269
					£ 877,460	**£ 4,037,082**	**£ 143,978**

Option Summary

PV Enabling Costs			**£**	**459,622**
PV Preliminary Costs			**£**	**417,838**
PV Construction Costs			**£**	**4,037,082**
	Element 1	£	563,650	
	Element 2	£	807,093	
	Element 3	£	2,085,786	
	Element 4	£	624,405	
	Element 5	£	97,446	
PV Operation and Maintenance Costs			**£**	**143,978**
Optimism Bias (60%)			**£**	**3,035,112**
Total Cost			**£**	**8,093,632**

Option Description Langholm

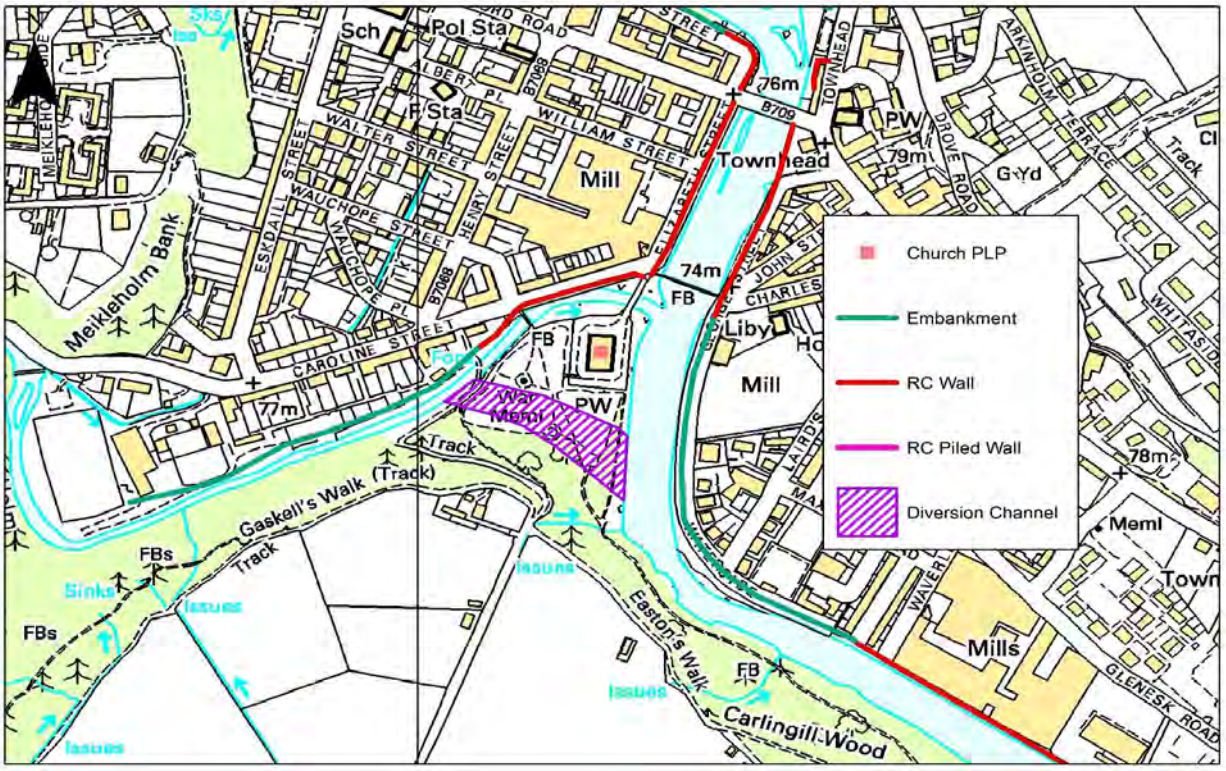
Option 2 - Direct Defences with Diversion Channel

Option 2 consists of 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 is provided to the Church of Scotland.

List of elements

1. Earth Embankment
2. RC Retaining Wall Type 1
3. RC Wall with Piled Base
4. RC Retaining Wall Type 2
5. Diversion Channel
6. Spill weir
7. PLP

Sketch of Option



Element 1 Construction Costs

Earth Embankment

Quantities generated from GIS modelling and a standard embankment cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Slope (1:X)	Cut-off depth	Crest width	CSA	Surface width	Footprint
1	49.95	1.2	2.5	0.75	1	5.55	7.46	789.13
2	49.70	1.48	2.5	0.75	1	7.71	8.97	840.87
3	49.47	1.16	2.5	0.75	1	5.27	7.25	773.64
4	48.82	1.12	2.5	0.75	1	5.01	7.03	755.79
5	49.95	1.3	2.5	0.75	1	6.28	8.00	809.16
6	40.96	1.5	2.5	0.75	1	7.87	9.08	696.38
7	58.82	1.1	2.5	0.75	1	4.88	6.92	905.86
8	50.00	0.7	2.5	0.75	1	2.67	4.77	690.00
9	37.46	1.1	2.5	0.75	1	4.88	6.92	576.87
10	50.10	1.2	2.5	0.75	1	5.55	7.46	791.50
11	49.11	1.48	2.5	0.75	1	7.71	8.97	830.96
12	49.22	1.63	2.5	0.75	1	9.02	9.78	862.26
13	50.31	1.78	2.5	0.75	1	10.45	10.59	911.63
14	50.32	2.05	2.5	0.75	1	13.31	12.04	966.05
15	47.68	2	2.5	0.75	1	12.75	11.77	905.94
16	46.30	0.95	2.5	0.75	1	3.96	6.12	685.27
17	33.74	1.47	2.5	0.75	1	7.62	8.92	569.57
18	22.14	2.32	2.5	0.75	1	16.53	13.49	448.92
19	17.06	2.22	2.5	0.75	1	15.29	12.96	339.22
20	24.42	2.6	2.5	0.75	1	20.25	15.00	522.58
21	31.16	2.1	2.5	0.75	1	13.88	12.31	604.55
22	23.95	1.38	2.5	0.75	1	6.89	8.43	395.73

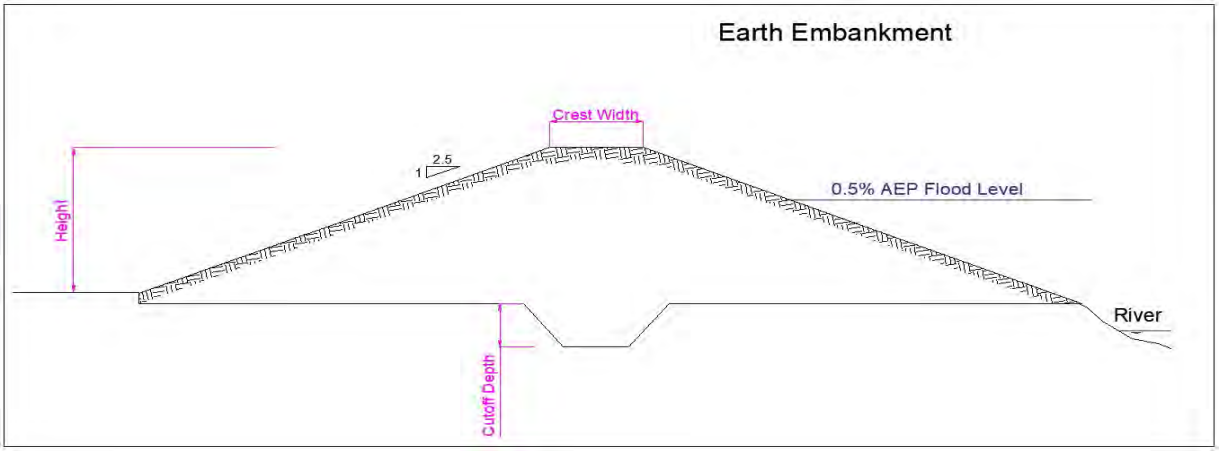
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	2	ha	£230	Prev. Job	£360
2.	Clearance - Site clearance & disposal	15672	m²	£5	Prev. Job	£78,359
3.	Excavation - Topsoil strip & stockpile	4702	m³	£3	Prev. Job	£14,105
4.	Excavation - Cutting	698	m³	£5	Prev. Job	£3,511
5.	Disposal - Cutting	698	m³	£26	Prev. Job	£17,896
6.	Filling - Provision of topsoil	2474	m³	£16	Prev. Job	£39,589
7.	Filling - Topsoil (300mm depth)	2474	m³	£9	Prev. Job	£21,031
8.	Filling - Provision of clay fill	7467	m³	£25	Prev. Job	£186,685
9.	Filling - Placing of clay fill	7467	m³	£9	Prev. Job	£63,473
10.	Geotextile mat	8248	m²	£3	Prev. Job	£24,743
11.	Finishing - Grassing out	15672	m²	£1	Prev. Job	£16,455
12.	Drainage	931	m	£35	Prev. Job	£32,572
					Total construction cost	**£498,780**

Verification of Cost - SEPA UCD Embankments

Embankment volume	Average Cost (£/m^3)	Total Construction Cost
5,000m^3 - 15,000m^3	65	£ 561,562

Sketch of Element



Element 2 Construction Costs

Reinforced Concrete Retaining Wall - Type 1

Quantities generated from GIS modelling and a standard flood wall cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	25.44	1.40	0.4	0.4	1.80	300.16	0.76	0.72
2	19.79	1.00	0.4	0.4	1.40	225.60	0.60	0.56
3	50.31	1.10	0.4	0.4	1.50	578.60	0.64	0.60
4	50.41	1.57	0.4	0.4	1.97	603.43	0.83	0.79
5	50.11	1.80	0.4	0.4	2.20	611.35	0.92	0.88
6	28.89	1.65	0.4	0.4	2.05	348.12	0.86	0.82
7	16.39	1.09	0.4	0.4	1.49	188.34	0.64	0.60
8	49.53	1.28	0.4	0.4	1.68	578.47	0.71	0.67
9	50.75	1.39	0.4	0.4	1.79	598.34	0.76	0.72
10	49.94	1.89	0.4	0.4	2.29	613.75	0.96	0.92
11	50.79	1.94	0.4	0.4	2.34	626.81	0.98	0.94
13	22.16	1.40	0.4	0.4	1.80	261.54	0.76	0.72
					1.81			

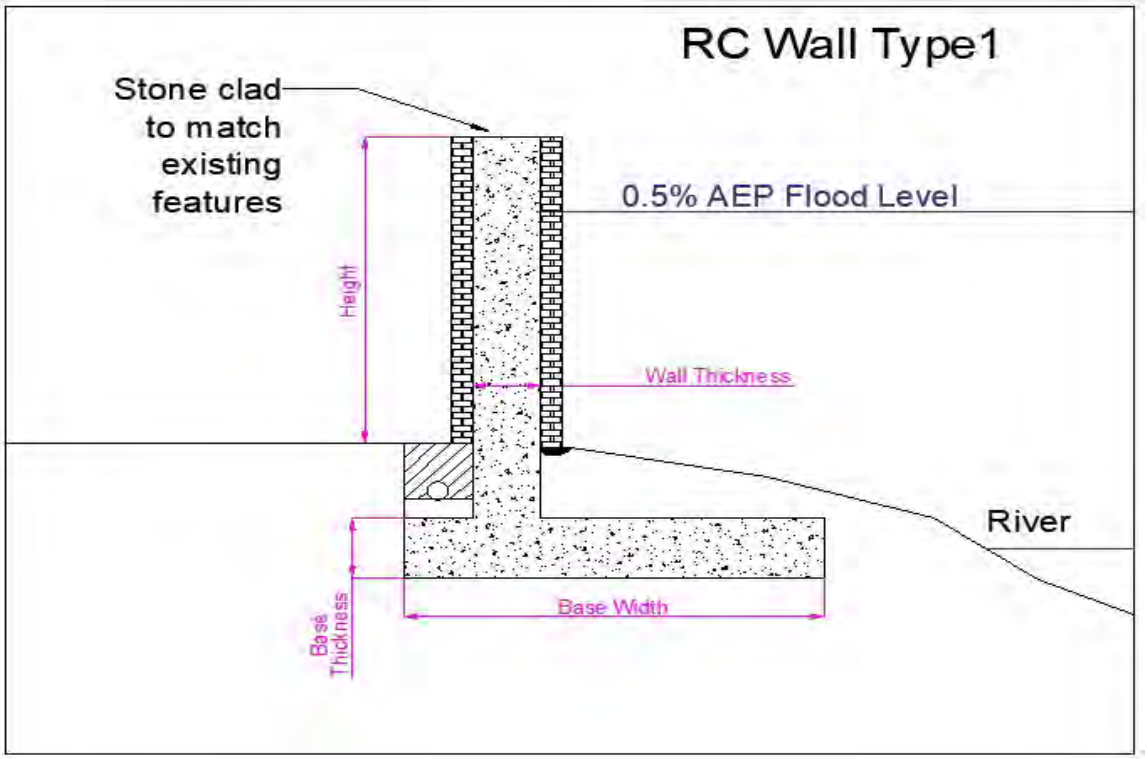
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.55	ha	£230	Prev. Job	£127
2.	Clearance - Site clearance & disposal	5535	m²	£5	Prev. Job	£27,673
3.	Excavation - Topsoil strip & stockpile	5535	m³	£3	Prev. Job	£16,604
4.	Excavation - Cutting	589	m³	£5	Prev. Job	£2,960
5.	Disposal - Cutting	589	m³	£26	Prev. Job	£15,090
6.	Base Slab - Concrete	356	m³	£200	Prev. Job	£71,146
7.	Base Slab - Reinforcement	28	t	£1,500	Prev. Job	£42,154
8.	Base Slab - Trench fill	889	m³	£75	Prev. Job	£66,699
9.	Base Slab - Formwork	372	m³	£110	Prev. Job	£40,878
10.	Wall - Concrete	374	m³	£200	Prev. Job	£74,862
11.	Wall - Reinforcement	30	t	£1,500	Prev. Job	£44,356
12.	Wall - Formwork	1872	m²	£110	Prev. Job	£205,871
13.	Wall - Finish (Granite)	1407	m²	£80	Prev. Job	£112,563
14.	Drainage	465	m	£50	Prev. Job	£23,226
					Total construction cost	**£744,209**

Verification of Cost - SEPA UCD Flood Walls

Size	Average Cost (£/m)	Total Construction Cost
1.2 -2.1m	**2641**	**£ 1,226,750**
Size	**Upper Cost (£/m)**	**Total Construction Cost**
1.2 -2.1m	**4591**	**£ 2,132,602**

Sketch of Element



Element 3 Construction Costs

Reinforced Concrete & Pile Flood Wall

Quantities generated from GIS modelling and a standard flood wall with piled foundation cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	52.04	2.32	0.4	0.8	0.80	562.02	1.13	0.64
2	50.59	2.25	0.4	0.8	0.80	546.34	1.10	0.64
3	49.95	2.03	0.4	0.8	0.80	539.49	1.01	0.64
4	48.96	2.10	0.4	0.8	0.80	528.78	1.04	0.64
5	51.10	2.30	0.4	0.8	0.80	551.83	1.12	0.64
6	49.78	1.83	0.4	0.8	0.80	537.57	0.93	0.64
7	52.41	1.66	0.4	0.8	0.80	565.98	0.86	0.64
8	46.96	1.44	0.4	0.8	0.80	507.21	0.78	0.64
9	51.00	1.15	0.4	0.8	0.80	550.84	0.66	0.64
10	49.63	1.20	0.4	0.8	0.80	536.02	0.68	0.64
11	46.30	1.19	0.4	0.8	0.80	500.06	0.68	0.64

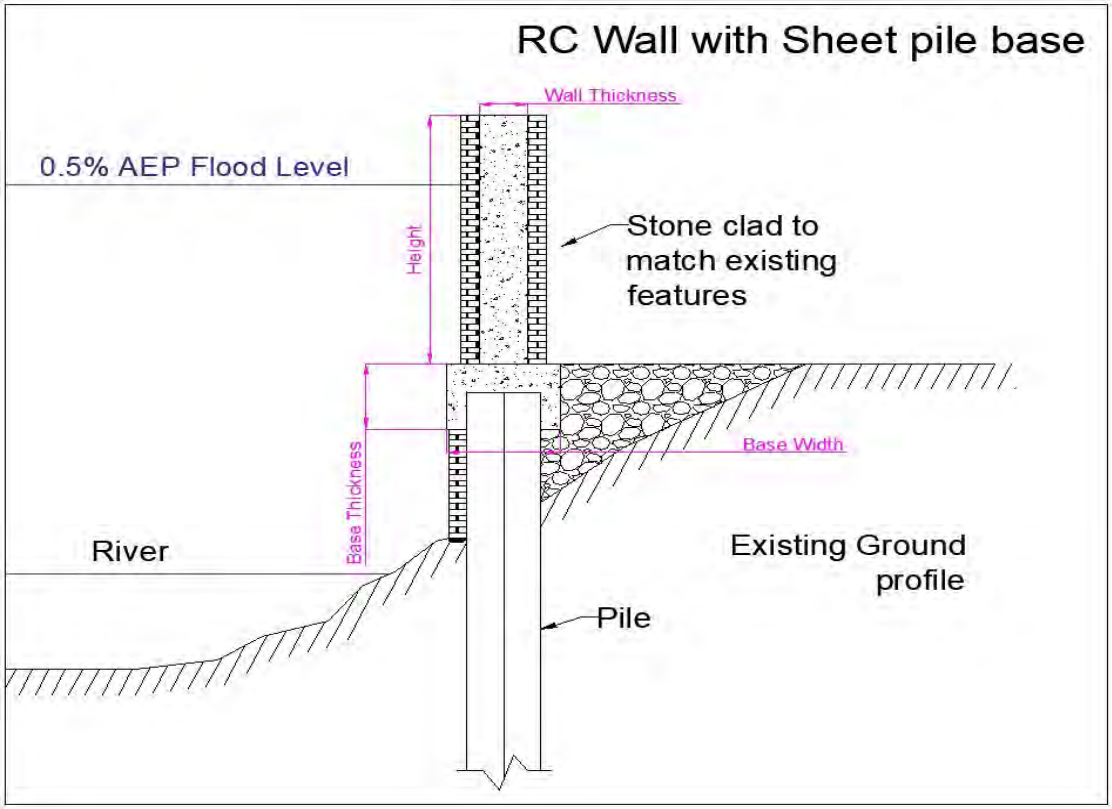
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.593	ha	£230	Prev. Job	£136
2.	Clearance - Site clearance & disposal	5926	m²	£5	Prev. Job	£29,631
3.	Excavation - Topsoil strip & stockpile	5926	m³	£3	Prev. Job	£17,778
4.	Excavation - Cutting	823	m³	£5	Prev. Job	£4,140
5.	Disposal - Cutting	823	m³	£26	Prev. Job	£21,104
6.	Base Slab - Concrete	432	m³	£200	Prev. Job	£86,313
7.	Base Slab - Reinforcement	28	t	£1,500	Prev. Job	£41,615
8.	Base Slab - Trench fill	439	m³	£75	Prev. Job	£32,923
9.	Base Slab - Formwork	878	m³	£110	Prev. Job	£96,574
10.	Wall - Concrete	1000	m³	£200	Prev. Job	£199,948
11.	Wall - Reinforcement	39	t	£1,500	Prev. Job	£59,234
12.	Wall - Formwork	2499	m²	£110	Prev. Job	£274,928
13.	Pile - Provision & Placement	549	m	£1,893	Prev. Job	£1,038,446
14.	Wall - Finish (Granite)	1951	m²	£80	Prev. Job	£156,050
15.	Drainage	549	m	£50	Prev. Job	£27,436
					Total construction cost	**£2,086,257**

Verification of Cost - SEPA UCD Floodwall & Pile

Size	Average Wall Cost (£/m)	Construction Cost
1.2 -2.1m	**2390**	**£ 1,311,433**
Size	**Lower Pile Cost (£/m)**	**Construction Cost**
Length >100m	**1309**	**£ 718,270**
	Total:	**£ 2,029,703**

Sketch of Element



Element 4 Construction Costs

Reinforced Concrete Retaining Wall - Type 2

Quantities generated from GIS modelling and a standard retaining flood wall cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Protruding Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	50.00	1.09	0.70	0.4	0.4	0.40	520.00	0.64	0.16
2	49.65	2.17	1.20	0.4	0.4	0.64	528.30	1.07	0.26
3	100.13	1.79	1.00	0.4	0.4	0.52	1053.57	0.92	0.21
4	73.00	4.00	1.20	0.4	0.4	1.85	864.90	1.80	0.74

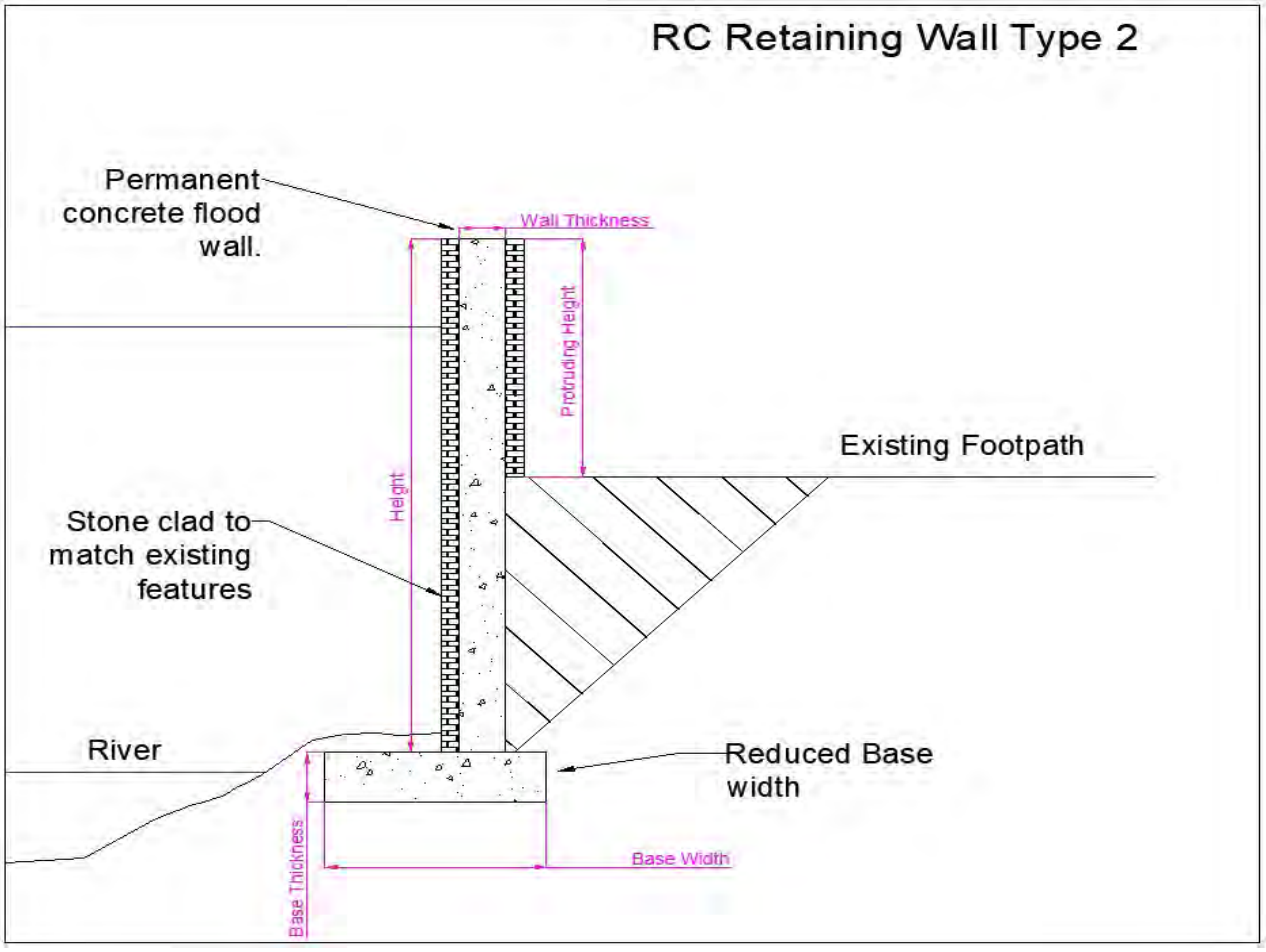
Cost Breakdown

Description	Quantity	Unit	Rate	Source	Total	
1. Clearance - Vegetation killing	0.297	ha	£230	Prev. Job	£	68
2. Clearance - Site clearance & disposal	2967	m²	£5	Prev. Job	£	14,834
3. Excavation - Topsoil strip & stockpile	2967	m³	£3	Prev. Job	£	8,900
4. Excavation - Cutting	163	m³	£5	Prev. Job	£	819
5. Disposal - Cutting	163	m³	£26	Prev. Job	£	4,174
4. Base Slab - Concrete	96	m³	£200	Prev. Job	£	19,117
5. Base Slab - Reinforcement	8	t	£1,500	Prev. Job	£	11,327
6. Base Slab - Trench fill	239	m³	£75	Prev. Job	£	17,922
7. Base Slab - Formwork	218	m³	£110	Prev. Job	£	24,005
8. Wall - Concrete	177	m³	£200	Prev. Job	£	35,317
9. Wall - Reinforcement	24	t	£1,500	Prev. Job	£	36,496
10. Wall - Formwork	1540	m²	£110	Prev. Job	£	169,392
11. Wall - Finish (Granite)	950	m²	£80	Prev. Job	£	76,029
12. Drainage	273	m	£50	Prev. Job	£	13,639
				Total construction cost	**£**	**432,040**

Verification of Cost - SEPA UCD Flood Walls

Size	Lower Cost (£/m)	Total Construction Cost
1.2 -2.1m	**1144**	**£ 228,549**

Sketch of Element



Element 5 Construction Costs

Diversion Channel

The diversion channel would be approximately 200m long, 34m wide and 1.5m in depth. The channel would be profiled in such a way as to allow it to be a public amenity area during normal flow conditions.

Quantities

Section	Length (m)	Average Width (m)	Average Depth (m)	Working Area (m2)	CSA (m^2)	Average Cross Sectional Perimeter (m)	Excavation (m^3)
1	202.00	34.00	1.50	8888.00	51.00	55.70	10302.00

Utility drawings in the area indicate that 5no. Service routes run through the line of the proposed channel.

Cost Breakdown

Description	Quantity	Unit	Rate	Rate source	Total
1. Clearance - Vegetation Killing	0.89	ha	£230.00	Previous Job	£204
2. Strip Topsoil	2666.40	m^3	£5.00	Previous Job	£13,332
3. Excavate Cutting (m^3)	10302.00	m^3	£5.03	Previous Job	£51,819
4. Disposal of Excavated Material	10302.00	m^3	£25.64	SEPA UCD	£264,143
5. Geotextile mat	11655.40	m^3	£3.00	Previous Job	£34,966.20
6. Seeding - Hydraulic Mulch Grass Seeding	11655.40	m^3	£1.92	SEPA UCD	£22,378.37
7. Topsoiling of Sloping Surfaces	6060.00	m^2	£5.41	SEPA UCD	£32,784.60
8. Topsoiling of Horizontal Surfaces	5191.40	m^2	£5.41	SEPA UCD	£28,085.47
9. Channel/Park Landscaping	1	Item	£30,000.00	SEPA UCD	£30,000.00
10. Disruption to Services - Water/Sewage Pipe Crossing	5	item	£10,000.00	Previous Job	£50,000.00
				Total construction cost	**£ 527,713**

Element 2 Construction Costs

Reinforced Concrete Retaining Wall - Type 1

Quantities generated from GIS modelling and a standard flood wall cross sectional makeup (see sketch). Rates generated from previous jobs, SPONS and the SEPA UCD as indicated below.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	18.50	1.80	0.4	0.4	2.20	225.70	0.92	0.88
2	18.50	1.80	0.4	0.4	2.20	225.70	0.92	0.88

Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.05	ha	£230	Prev. Job	£10
2.	Clearance - Site clearance & disposal	451	m²	£5	Prev. Job	£2,257
3.	Excavation - Topsoil strip & stockpile	451	m³	£3	Prev. Job	£1,354
4.	Base Slab - Concrete	33	m³	£200	Prev. Job	£6,512
5.	Base Slab - Reinforcement	3	t	£1,500	Prev. Job	£3,858
6.	Base Slab - Trench fill	81	m³	£75	Prev. Job	£6,105
7.	Base Slab - Formwork	30	m³	£110	Prev. Job	£3,256
8.	Wall - Concrete	34	m³	£200	Prev. Job	£6,808
9.	Wall - Reinforcement	3	t	£1,500	Prev. Job	£4,034
10.	Wall - Formwork	170	m²	£110	Prev. Job	£18,722
					Total construction cost	**£52,917**

Verification of Cost - SEPA UCD Flood Walls

Size	Average Cost (£/m)	Total Construction Cost
1.2 -2.1m	**2905**	**£ 107,485**
Size	**Upper Cost (£/m)**	**Total Construction Cost**
1.2 -2.1m	**4591**	**£ 169,867**

Element 7 Construction Costs

Property Level Protection

PLP costing estimates are taken from the SEPA Costing of Flood Rsk Management Measures (F4006), Category 4 - Resililence Measures. Note: For this costing, the church is estimated to be the equivelent of 3 detached properties.

SEPA UCD Flood Walls - Table 3.3 (£ per Property)

Category	Detached Property	Total Construction Cost	
Without floor - Upper	**32482**		**£ 97,446**

Enabling and Preliminary Costs

Preliminary costs include for work required before construction takes place. Examples include the setting up of the site compound area, surveys (structural, environmental, etc.), traffic management, provision of temporary access, watercourse management. A percentage of the construction costs is assumed as previous scheme have shown a relationship between the size of scheme's construction costs and the preliminary costs. A range of 10% - 30% is typical. The percentage assumed has also been based on factors such as the remoteness of the works, if there are known environmental and technical restrictions or whether it's in a heavily urbanised area.
Enabling costs cover items required before the construction and preliminary works can take place. This includes items such as professional fees, design, consultation, modelling, licence/planning fees. A percentage of the capital costs (construction + preliminary) is assumed as previous schemes have shown a relationship between the size of the scheme's capital costs and the enabling costs. Although each option comprises of multiple elements which may result in a specific enabling cost percentage the overall option has been considered when carrying out this estimation.

Preliminary Costs

Option Construction Costs	£	4,439,362
Preliminary Cost Percentage		10%
Preliminary Costs (£)	£	443,936
Assumptions	A lower estimate for preliminary costs has been used for this costing as the overall cost of the scheme is large.	

Enabling Costs

Option Capital Costs	£	4,883,298
Enabling Cost Percentage		10%
Enabling Costs (£)	£	488,330
Assumptions	The SEPA UCD indicates that the estimated enabling cost as a percentage of the scheme costs should range between 8 - 10 % for schemes > £1000k. Therefore a conservative value of 10% was used in costing this scheme.	

Operation and Maintenance

The various elements of this option will have associated operation and maintenance (O&M) costs. Costs are dependant on the responsible body (eg local authority, government body, private party), the complexity of the element (eg moving parts, high precision tolerances), and the robustness of the element (eg rate of degradation, risk of collapse).

Element 1 - Earth Embankment

Annual O&M cost	£	2,536
Assumptions	Cost based on a rate of £2,725/km/year. Maintenance includes for vegetation control, inspections, vermin control, back drainage improvements.	

Element 2 - RC Flood Wall

Annual O&M cost	£	262
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 3 - RC Flood Wall & Pile

Annual O&M cost	£	310
Assumptions	Cost based on a rate of £0.565 per m per annum for the RC wall & Pile. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 4 - RC Retaining Flood Wall

Annual O&M cost	£	113
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 5 - Diversion Channel

Annual O&M cost	£	53
Assumptions	Cost based on rate of £260 per/km/year. Maintenance includes visual inspections, reactive obstruction removal, vegetation management, vermin control and minor bank repair works.	

Element 6 - Diversion Spill weir

Annual O&M cost	£	500
Assumptions	Includes for inspection, maintenance and repairs.	

Element 7 - PLP

Annual O&M cost	£	1,949
Assumptions	Cost of maintenance based on paragraph 3.1.5 of SPA UC. Suggesting 2% of Capital Costs (£300-£900) per property per annum. = 0.02*97446 = £1949pa	

Total O&M Annual Costs

O&M costs per year	**£**	**5,723**

Whole Life Cost

Design Life

1.	Earth Embankment	100yrs
2.	RC Retianing Wall - Type 1	100yrs
3.	RC Wall & Pile	100yrs
4.	RC Retianing Wall - Type 2	100yrs
5.	Diversion Channel	100yrs
6.	Spill Weir	100yrs
7.	PLP	100yrs

Financial Assumptions

Financial period	100yrs
Discount rate	3.5% for year 0-30, 3% for year 31-75, 2.5% for year 76-99

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
0	1.000	932,266			932,266	-	-
1	0.966		4,439,362		-	4,289,239	-
2	0.934			5,723	-	-	5,342
3	0.902			5,723	-	-	5,162
4	0.871			5,723	-	-	4,987
5	0.842			5,723	-	-	4,818
6	0.814			5,723	-	-	4,656
7	0.786			5,723	-	-	4,498
8	0.759			5,723	-	-	4,346
9	0.734			5,723	-	-	4,199
10	0.709			5,723	-	-	4,057
11	0.685			5,723	-	-	3,920
12	0.662			5,723	-	-	3,787
13	0.639			5,723	-	-	3,659
14	0.618			5,723	-	-	3,535
15	0.597			5,723	-	-	3,416
16	0.577			5,723	-	-	3,300
17	0.557			5,723	-	-	3,189
18	0.538			5,723	-	-	3,081
19	0.520			5,723	-	-	2,977
20	0.503			5,723	-	-	2,876
21	0.486			5,723	-	-	2,779
22	0.469			5,723	-	-	2,685
23	0.453			5,723	-	-	2,594
24	0.438			5,723	-	-	2,506
25	0.423			5,723	-	-	2,422
26	0.409			5,723	-	-	2,340
27	0.395			5,723	-	-	2,261
28	0.382			5,723	-	-	2,184
29	0.369			5,723	-	-	2,110
30	0.356			5,723	-	-	2,039
31	0.346			5,723	-	-	1,980
32	0.336			5,723	-	-	1,922
33	0.326			5,723	-	-	1,866
34	0.317			5,723	-	-	1,812
35	0.307			5,723	-	-	1,759
36	0.298			5,723	-	-	1,708
37	0.290			5,723	-	-	1,658
38	0.281			5,723	-	-	1,610
39	0.273			5,723	-	-	1,563
40	0.265			5,723	-	-	1,517

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
41	0.257			5,723	-	-	1,473
42	0.250			5,723	-	-	1,430
43	0.243			5,723	-	-	1,388
44	0.236			5,723	-	-	1,348
45	0.229			5,723	-	-	1,309
46	0.222			5,723	-	-	1,271
47	0.216			5,723	-	-	1,234
48	0.209			5,723	-	-	1,198
49	0.203			5,723	-	-	1,163
50	0.197			5,723	-	-	1,129
51	0.192			5,723	-	-	1,096
52	0.186			5,723	-	-	1,064
53	0.181			5,723	-	-	1,033
54	0.175			5,723	-	-	1,003
55	0.170			5,723	-	-	974
56	0.165			5,723	-	-	945
57	0.160			5,723	-	-	918
58	0.156			5,723	-	-	891
59	0.151			5,723	-	-	865
60	0.147			5,723	-	-	840
61	0.143			5,723	-	-	816
62	0.138			5,723	-	-	792
63	0.134			5,723	-	-	769
64	0.130			5,723	-	-	746
65	0.127			5,723	-	-	725
66	0.123			5,723	-	-	703
67	0.119			5,723	-	-	683
68	0.116			5,723	-	-	663
69	0.112			5,723	-	-	644
70	0.109			5,723	-	-	625
71	0.106			5,723	-	-	607
72	0.103			5,723	-	-	589
73	0.100			5,723	-	-	572
74	0.097			5,723	-	-	555
75	0.094			5,723	-	-	539
76	0.092			5,723	-	-	526
77	0.090			5,723	-	-	513
78	0.087			5,723	-	-	501
79	0.085			5,723	-	-	488
80	0.083			5,723	-	-	477
81	0.081			5,723	-	-	465
82	0.079			5,723	-	-	454
83	0.077			5,723	-	-	443
84	0.075			5,723	-	-	432
85	0.074			5,723	-	-	421
86	0.072			5,723	-	-	411
87	0.070			5,723	-	-	401
88	0.068			5,723	-	-	391
89	0.067			5,723	-	-	382
90	0.065			5,723	-	-	372
91	0.063			5,723	-	-	363
92	0.062			5,723	-	-	354
93	0.060			5,723	-	-	346
94	0.059			5,723	-	-	337
95	0.057			5,723	-	-	329
96	0.056			5,723	-	-	321
97	0.055			5,723	-	-	313
98	0.053			5,723	-	-	306
99	0.052			5,723	-	-	298
					£ 932,266	**£ 4,289,239**	**£ 159,361**

Option Summary

PV Enabling Costs			**£**	**488,330**
PV Preliminary Costs			**£**	**443,936**
PV Construction Costs			**£**	**4,289,239**
	Element 1	£	498,780	
	Element 2	£	744,209	
	Element 3	£	2,086,257	
	Element 4	£	432,040	
	Element 5	£	527,713	
	Element 6	£	52,917	
	Element 7	£	97,446	
£	**932,266**			
PV Operation and Maintenance Costs			**£**	**159,361**
Optimism Bias (60%)			**£**	**3,228,519**
Total Cost			**£**	**8,609,384**

Option Description Langholm

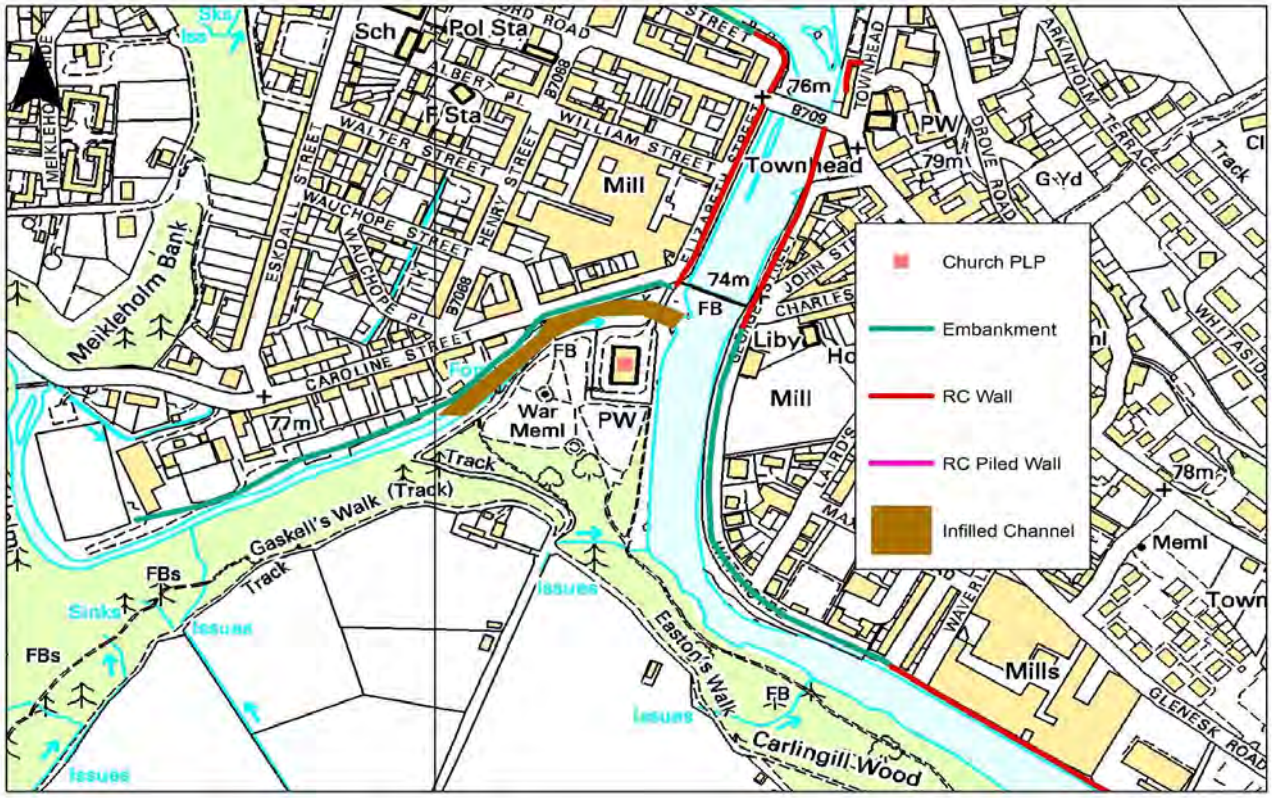
Option 3 - Direct Defences with Re- Route Channel

Option 3 consists of 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 will be provided to the Church of Scotland.

List of elements

1. Earth Embankment
2. RC Retaining Wall Type 1
3. RC Wall with Piled Base
4. RC Retaining Wall Type 2
5. Re-routed Channel
6. PLP

Sketch of Option



Element 1 Construction Costs

Earth Embankment

Option 3 consists of 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 will be provided to the Church of Scotland.

Quantities

Section	Length	Height	Slope (1:X)	Cut off depth	Crest width	CSA	Surface width	Footprint
1	49.95	1.27	2.5	0.75	1	6.05	7.84	803.12
2	49.70	1.43	2.5	0.75	1	7.29	8.70	830.93
3	49.47	1.17	2.5	0.75	1	5.34	7.30	775.62
4	16.39	0.97	2.5	0.75	1	4.07	6.22	243.91
5	49.53	1.17	2.5	0.75	1	5.34	7.30	776.57
6	50.75	1.27	2.5	0.75	1	6.05	7.84	816.06
7	49.94	1.77	2.5	0.75	1	10.35	10.53	902.89
8	50.79	1.77	2.5	0.75	1	10.35	10.53	918.37
9	48.82	1.15	2.5	0.75	1	5.21	7.19	761.65
10	49.95	1.40	2.5	0.75	1	7.05	8.54	829.14
11	40.96	1.50	2.5	0.75	1	7.87	9.08	696.38
12	58.82	1.20	2.5	0.75	1	5.55	7.46	929.39
13	50.00	0.71	2.5	0.75	1	2.72	4.82	692.00
14	37.46	1.10	2.5	0.75	1	4.88	6.92	576.87
15	50.10	1.19	2.5	0.75	1	5.48	7.41	789.50
16	49.11	1.47	2.5	0.75	1	7.62	8.92	829.00
17	49.22	1.56	2.5	0.75	1	8.39	9.40	848.48
18	50.31	2.01	2.5	0.75	1	12.86	11.82	957.91
19	50.32	2.01	2.5	0.75	1	12.86	11.82	958.00
20	47.68	2.01	2.5	0.75	1	12.86	11.82	907.85
21	33.74	1.47	2.5	0.75	1	7.62	8.92	569.57
22	22.14	2.20	2.5	0.75	1	15.05	12.85	438.29
23	17.06	2.25	2.5	0.75	2	18.66	14.12	358.33
24	24.42	2.57	2.5	0.75	3	26.47	16.84	568.49
25	31.16	2.10	2.5	0.75	4	22.43	15.31	698.04
26	23.95	1.32	2.5	0.75	5	14.71	12.11	485.80

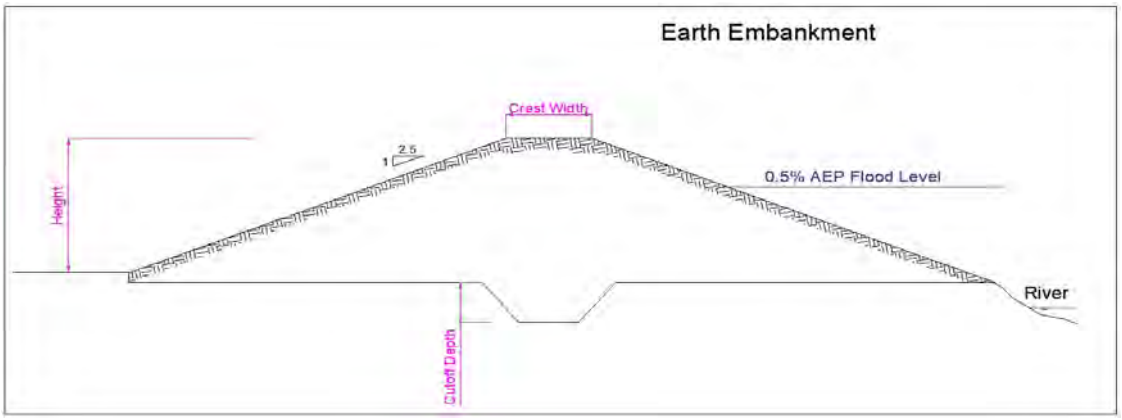
Cost Breakdown

Description	Quantity	Unit	Rate	Source	Total
1. Clearance - Vegetation killing	2	ha	£230	Prev. Job	£436
2. Clearance - Site clearance & disposal	18962	m²	£5	Prev. Job	£94,811
3. Excavation - Topsoil strip & stockpile	5689	m³	£3	Prev. Job	£17,066
4. Excavation - Cutting	826	m³	£5	Prev. Job	£4,131
5. Disposal - Cutting	826	m³	£26	Prev. Job	£21,484
6. Filling - Provision of topsoil	3068	m³	£16	Prev. Job	£49,086
7. Filling - Topsoil (300mm depth)	3068	m³	£9	Prev. Job	£26,077
8. Filling - Provision of clay fill	9760	m³	£25	Prev. Job	£243,993
9. Filling - Placing of clay fill	9760	m³	£9	Prev. Job	£82,958
10. Geotextile mat	10226	m²	£3	Prev. Job	£30,678
11. Finishing - Grassing out	18962	m²	£1	Prev. Job	£19,910
12. Drainage	1102	m	£35	Prev. Job	£38,561
				Total construction cost	**£629,190**

Verification of Cost - SEPA UCD Embankments

Embankment volume	Average Cost (£/m^3)	Total Construction Cost
5,000m^3 - 15,000m^3	65	£ 693,051

Sketch of Element



Element 2 Construction Costs

Reinforced Concrete Retaining Wall - Type 1

Option 3 consists of 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 will be provided to the Church of Scotland.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	25.44	1.29	0.4	0.4	1.69	297.36	0.72	0.68
2	19.79	1.01	0.4	0.4	1.41	225.80	0.60	0.56
3	50.31	1.09	0.4	0.4	1.49	578.10	0.64	0.60
4	50.41	1.56	0.4	0.4	1.96	602.92	0.82	0.78
5	50.11	1.79	0.4	0.4	2.19	610.85	0.92	0.88
6	28.89	1.65	0.4	0.4	2.05	348.12	0.86	0.82
7	22.16	1.41	0.4	0.4	1.81	261.77	0.76	0.72

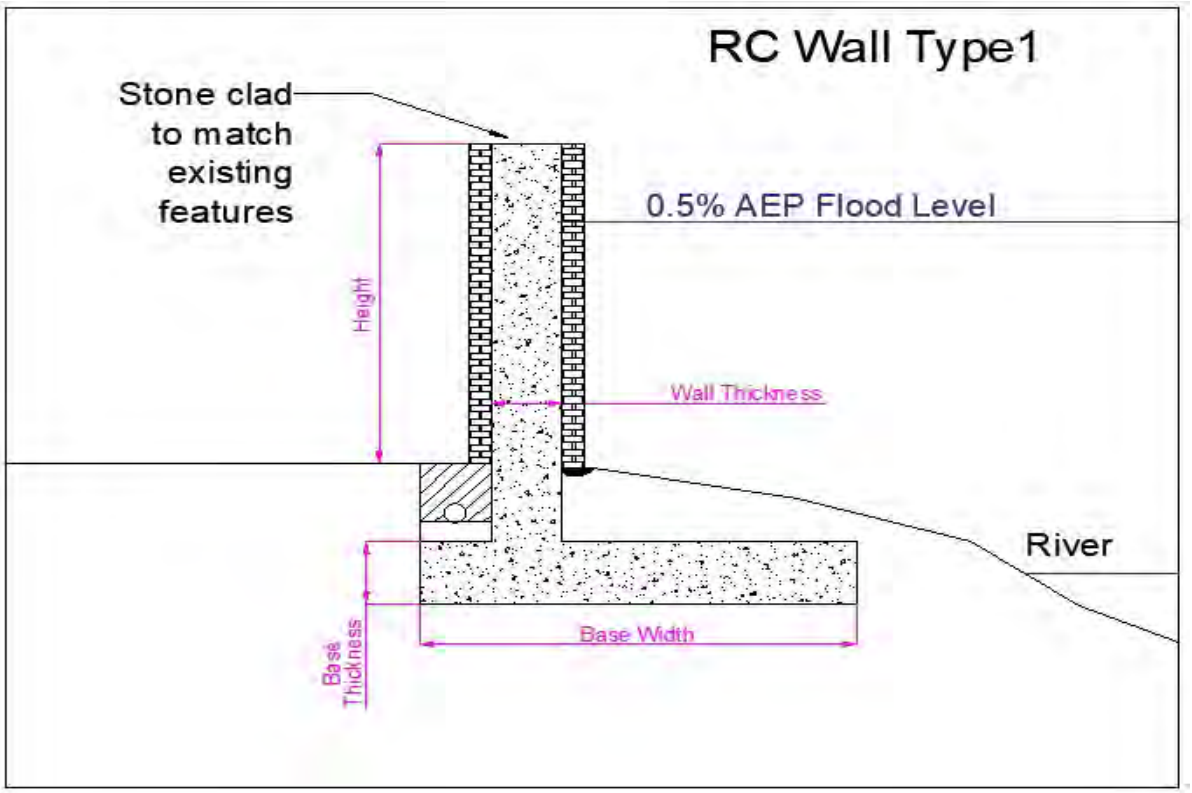
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.29	ha	£230	Prev. Job	£67
2.	Clearance - Site clearance & disposal	2925	m²	£5	Prev. Job	£14,625
3.	Excavation - Topsoil strip & stockpile	2925	m³	£3	Prev. Job	£8,775
4.	Base Slab - Concrete	181	m³	£200	Prev. Job	£36,300
5.	Base Slab - Reinforcement	14	t	£1,500	Prev. Job	£21,508
6.	Base Slab - Trench fill	454	m³	£75	Prev. Job	£34,031
7.	Base Slab - Formwork	198	m³	£110	Prev. Job	£21,746
8.	Wall - Concrete	191	m³	£200	Prev. Job	£38,277
9.	Wall - Reinforcement	15	t	£1,500	Prev. Job	£22,679
10.	Wall - Formwork	957	m²	£110	Prev. Job	£105,261
11.	Wall - Finish (Granite)	710	m²	£80	Prev. Job	£56,784
12.	Drainage	247	m	£50	Prev. Job	£12,356
					Total construction cost	**£372,409**

Verification of Cost - SEPA UCD Flood Walls

Size	Average Cost (£/m)	Total Construction Cost
1.2 -2.1m	**2905**	**£ 717,873**
Size	**Upper Cost (£/m)**	**Total Construction Cost**
1.2 -2.1m	**4591**	**£ 1,134,512**

Sketch of Element



Element 3 Construction Costs

Reinforced Concrete & Pile Flood Wall

Option 3 consists of 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 will be provided to the Church of Scotland.

Quantities

Section	Length	Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	52.04	2.20	0.4	0.8	0.80	562.02	1.08	0.64
2	50.59	2.22	0.4	0.8	0.80	546.34	1.09	0.64
3	49.95	1.91	0.4	0.8	0.80	539.49	0.96	0.64
4	48.96	2.05	0.4	0.8	0.80	528.78	1.02	0.64
5	51.10	2.25	0.4	0.8	0.80	551.83	1.10	0.64
6	49.78	1.80	0.4	0.8	0.80	537.57	0.92	0.64
7	52.41	1.50	0.4	0.8	0.80	565.98	0.80	0.64
8	46.96	1.39	0.4	0.8	0.80	507.21	0.76	0.64
9	51.00	1.15	0.4	0.8	0.80	550.84	0.66	0.64
10	49.63	1.20	0.4	0.8	0.80	536.02	0.68	0.64
11	46.30	1.12	0.4	0.8	0.80	500.06	0.65	0.64

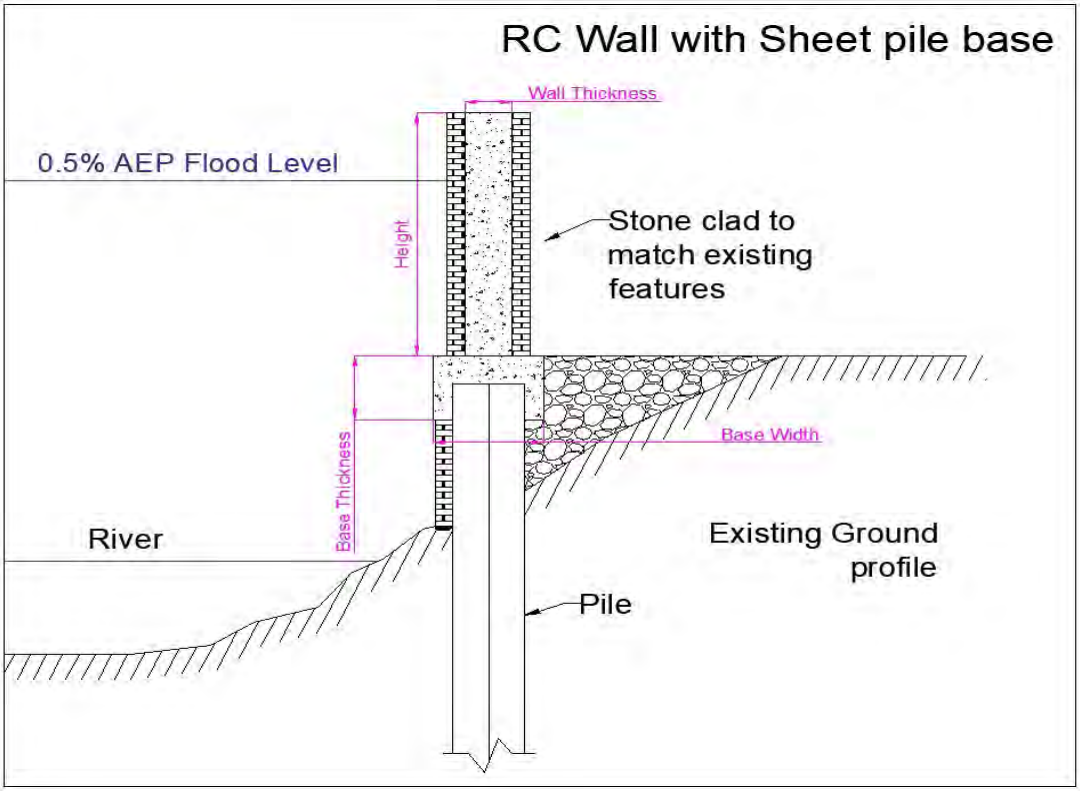
Cost Breakdown

	Description	Quantity	Unit	Rate	Source	Total
1.	Clearance - Vegetation killing	0.593	ha	£230	Prev. Job	£136
2.	Clearance - Site clearance & disposal	5926	m²	£5	Prev. Job	£29,631
3.	Excavation - Topsoil strip & stockpile	5926	m³	£3	Prev. Job	£17,778
4.	Excavation - Cutting	823	m³	£5	Prev. Job	£4,140
5.	Disposal - Cutting	823	m³	£26	Prev. Job	£21,104
6.	Base Slab - Concrete	432	m³	£200	Prev. Job	£86,313
7.	Base Slab - Reinforcement	28	t	£1,500	Prev. Job	£41,615
8.	Base Slab - Trenchfill	439	m³	£75	Prev. Job	£32,923
9.	Base Slab - Formwork	878	m³	£110	Prev. Job	£96,574
10.	Wall - Concrete	972	m³	£200	Prev. Job	£194,471
11.	Wall - Reinforcement	38	t	£1,500	Prev. Job	£57,612
12.	Wall - Formwork	2431	m²	£110	Prev. Job	£267,398
13.	Pile - Provision & Placement	549	m	£1,893	Prev. Job	£1,038,446
14.	Wall - Finish (Granite)	1882	m²	£80	Prev. Job	£150,574
15.	Drainage	549	m	£50	Prev. Job	£27,436
					Total construction cost	**£2,066,152**

Verification of Cost - SEPA UCD Floodwall & Pile

Size	Average Wall Cost (£/m)	Construction Cost
1.2 -2.1m	**2390**	**£ 1,311,433**
Size	**Lower Pile Cost (£/m)**	**Construction Cost**
Length >100m	**1309**	**£ 718,270**
	Total:	**£ 2,029,703**

Sketch of Element



Element 4 Construction Costs

Reinforced Concrete Retaining Wall - Type 2

Option 3 consists of 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 will be provided to the Church of Scotland.

Quantities

Section	Length	Height	Protruding Height	Wall Thickness	Base Thickness	Base Width	Working Width	Stem CSA	Base CSA
1	50.00	1.10	1.30	0.4	0.4	0.40	520.00	0.64	0.16
2	49.65	2.16	1.58	0.4	0.4	0.39	515.68	1.06	0.15
3	100.13	1.81	1.20	0.4	0.4	0.40	1041.61	0.92	0.16
4	73.00	4.01	1.35	0.4	0.4	1.76	858.16	1.80	0.70

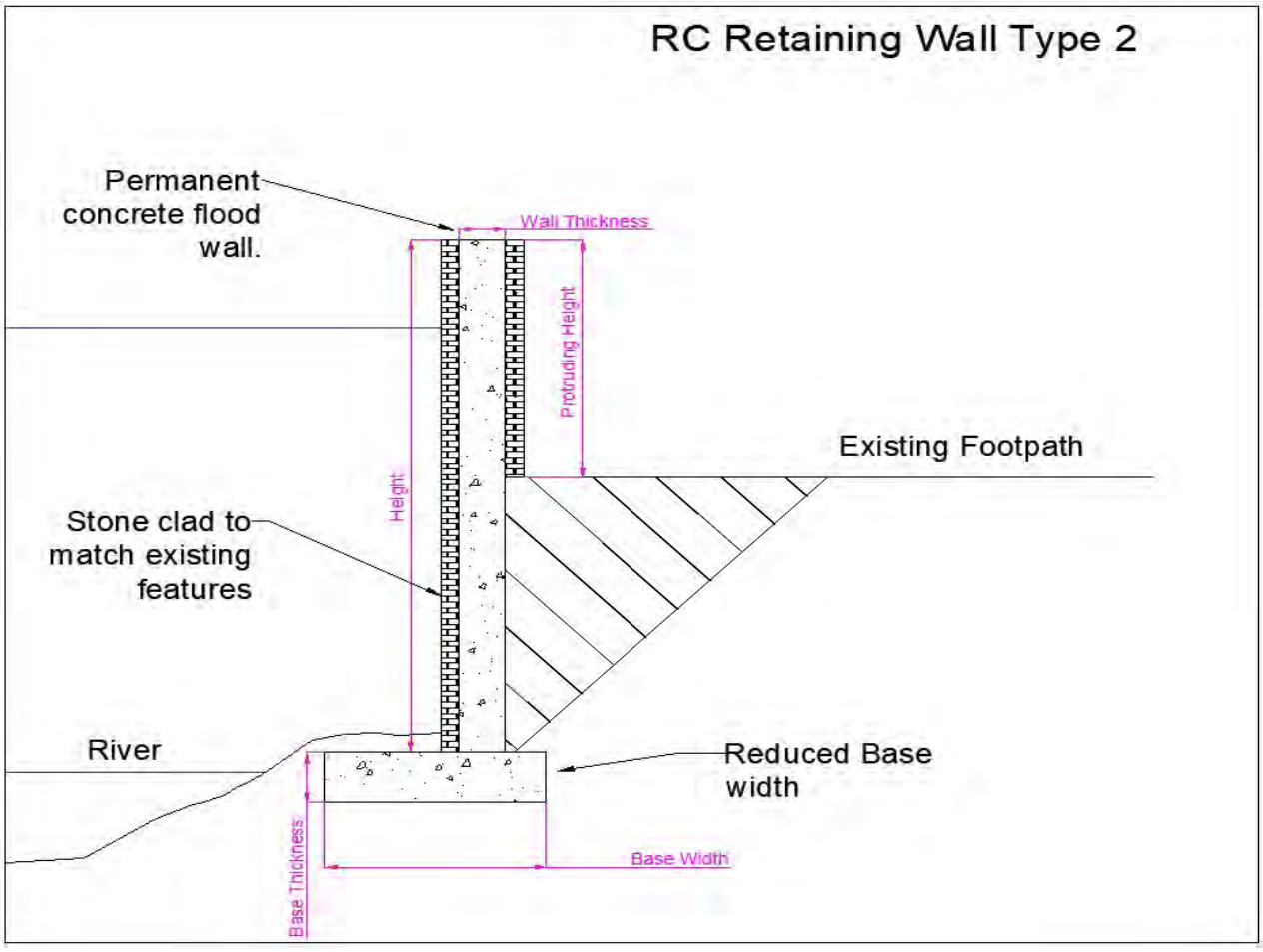
Cost Breakdown

Description	Quantity	Unit	Rate	Source	Total	
1. Clearance - Vegetation killing	0.294	ha	£230	Prev. Job	£	68
2. Clearance - Site clearance & disposal	2935	m²	£5	Prev. Job	£	14,677
3. Excavation - Topsoil strip & stockpile	2935	m³	£3	Prev. Job	£	8,806
4. Excavation - Cutting	141	m³	£5	Prev. Job	£	707
5. Disposal - Cutting	141	m³	£26	Prev. Job	£	3,604
4. Base Slab - Concrete	83	m³	£200	Prev. Job	£	16,611
5. Base Slab - Reinforcement	7	t	£1,500	Prev. Job	£	9,842
6. Base Slab - Trenchfill	208	m³	£75	Prev. Job	£	15,573
7. Base Slab - Formwork	218	m³	£110	Prev. Job	£	24,005
8. Wall - Concrete	177	m³	£200	Prev. Job	£	35,470
9. Wall - Reinforcement	24	t	£1,500	Prev. Job	£	36,621
10. Wall - Formwork	1545	m²	£110	Prev. Job	£	169,972
11. Wall - Finish (Granite)	954	m²	£80	Prev. Job	£	76,345
12. Drainage	273	m	£50	Prev. Job	£	13,639
				Total construction cost	**£**	**425,940**

Verification of Cost - SEPA UCD Flood Walls

Size	Lower Cost (£/m)	Total Construction Cost
1.2 -2.1m	**1144**	**£ 228,549**

Sketch of Element



Element 5 Construction Costs

Re-Routed Channel

Option 3 consists of 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 will be provided to the Church of Scotland.

Quantities

Section	Length (m)	Average Width (m)	Average Depth (m)	Working Area (m2)	CSA (m^2)	Average Cross Sectional Perimeter (m)	Excavation (m^3)
1	190.00	13.00	3.00	4370.00	39.00	21.40	7410.00

Utility drawings in the area indicate that 5no. Service routes run through the line of the proposed channel.

Cost Breakdown

Description	Quantity	Unit	Rate	Rate source	Total
1. Clearance - Vegetation Killing	0.44	ha	£230.00	Previous Job	£101
2. Strip topsoil	1083.00	m^3	£5.00	Previous Job	£5,415
3. Excavate Cutting (m^3)	7410.00	m^3	£5.03	SEPA UCD	£37,272
4. Disposal of Excavated Material offsite	3705.00	m^3	£25.64	SPONS	£94,996
4. Disposal of Excavated Material to infill	3705.00	m^3	£3.77	SEPA UCD	£13,968
4. Import of Clay Fill	3705.00	m^3	£25.00	SEPA UCD	£92,625
4. Compation of Material	3705.00	m^3	£9.00	SPONS	£33,345
5. Trim Excavated Material	4370.00	m^2	£1.84	SEPA UCD	£8,040.80
6. Form Horizontal Sloping Surface	1596.00	m^2	£1.62	SEPA UCD	£2,585.52
7. Bank Stabilisation	1596.00	m	£6.36	SEPA UCD	£10,150.56
8. Topsoiling of Sloping Surfaces	4560.00	m^2	£5.41	SEPA UCD	£24,669.60
9. Topsoiling of horizontal surfaces	2964.00	m^2	£5.41	SEPA UCD	£16,035.24
10. Seeding of Surfaces	4560.00	m^2	£1.92	SEPA UCD	£8,755.20
11. Landscaping	2.00	Item	£30,000	SEPA UCD	£60,000.00
12. Disruption to Services - Water/Sewage Pipe Crossing	5.00	Item	£10,000	Previous Job	£50,000.00
12. Removal of Existing Footbridge	1.00	Item	£15,000	SEPA UCD	£15,000.00

Total construction cost £ 472,959

Element 6 Construction Costs

Property Level Protection

PLP costing estimates are taken from the SEPA Costing of Flood Rsk Management Measures (F4006), Category 4 - Resililence Measures. Note: For this costing, the church is estimated to be the equivelent of 3 detached properties.

SEPA UCD Flood Walls - Table 3.3 (£ per Property)

Category	Detached Property	Total Construction Cost	
Without floor - Upper	**32482**		**£ 97,446**

Enabling and Preliminary Costs

Preliminary costs include for work required before construction takes place. Examples include the setting up of the site compound area, surveys (structural, environmental, etc.), traffic management, provision of temporary access, watercourse management. A percentage of the construction costs is assumed as previous scheme have shown a relationship between the size of scheme's construction costs and the preliminary costs. A range of 10% - 30% is typical. The percentage assumed has also been based on factors such as the remoteness of the works, if there are known environmental and technical restrictions or whether it's in a heavily urbanised area.
Enabling costs cover items required before the construction and preliminary works can take place. This includes items such as professional fees, design, consultation, modelling, licence/planning fees. A percentage of the capital costs (construction + preliminary) is assumed as previous schemes have shown a relationship between the size of the scheme's capital costs and the enabling costs. Although each option comprises of multiple elements which may result in a specific enabling cost percentage the overall option has been considered when carrying out this estimation.

Preliminary Costs

Option Construction Costs	£	4,064,097
Preliminary Cost Percentage		10%
Preliminary Costs (£)	£	406,410
Assumptions	A lower estimate for preliminary costs has been used for this costing as the overall cost of the scheme is large.	

Enabling Costs

Option Capital Costs	£	4,470,506
Enabling Cost Percentage		10%
Enabling Costs (£)	£	447,051
Assumptions	The SEPA UCD indicates that the estimated enabling cost as a percentage of the scheme costs should range between 8 - 10 % for schemes > £1000k. Therefore a conservative value of 10% was used in costing this scheme.	

Operation and Maintenance

The various elements of this option will have associated operation and maintenance (O&M) costs. Costs are dependant on the responsible body (eg local authority, government body, private party), the complexity of the element (eg moving parts, high precision tolerances), and the robustness of the element (eg rate of degradation, risk of collapse).

Annual O&M cost	£	3,002
Assumptions	Cost based on a rate of £2,725/km/year. Maintenance includes for vegetation control, inspections, vermin control, back drainage improvements.	

Element 2 - RC Flood Wall

Annual O&M cost	£	140
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 3 - RC Flood Wall & Pile

Annual O&M cost	£	310
Assumptions	Cost based on a rate of £0.565 per m per annum for the RC wall & Pile. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 4 - RC Retaining Flood Wall

Annual O&M cost	£	113
Assumptions	Cost based on a rate of £0.565 per m per annum. The O&M costs provide for cover vegetation clearance from the wall base, minor concrete repairs and wall repair works.	

Element 5 - Re-routed Channel

Annual O&M cost	£	49
Assumptions	Cost based on rate of £260 per/km/year. Maintenance includes visual inspections, reactive obstruction removal, vegetation management, vermin control and minor bank repair works.	

Element 6 - PLP

Annual O&M cost	£	1,949
Assumptions	Cost of maintenance based on paragraph 3.1.5 of SPA UC. Suggesting 2% of Capital Costs (£300-£900) per property per annum. = 0.02*97446 = £1949pa	

Total O&M Annual Costs

O&M costs per year	**£**	**5,563**

Whole Life Cost

Design Life

2.	Earth Embankment	100yrs
3.	RC Retaining Wall - Type	100yrs
4.	RC Wall & Pile	100yrs
5.	RC Retaining Wall - Type	100yrs
6.	Re-route	100yrs
7.	PLP	100yrs

Financial Assumptions

Financial period	100yrs
Discount rate	3.5% for year 0-30, 3% for year 31-75, 2.5% for year 76-99

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
0	1.000	853,460			853,460	-	-
1	0.966		4,064,097		-	3,926,663	-
2	0.934			5,563	-	-	5,193
3	0.902			5,563	-	-	5,018
4	0.871			5,563	-	-	4,848
5	0.842			5,563	-	-	4,684
6	0.814			5,563	-	-	4,526
7	0.786			5,563	-	-	4,373
8	0.759			5,563	-	-	4,225
9	0.734			5,563	-	-	4,082
10	0.709			5,563	-	-	3,944
11	0.685			5,563	-	-	3,810
12	0.662			5,563	-	-	3,682
13	0.639			5,563	-	-	3,557
14	0.618			5,563	-	-	3,437
15	0.597			5,563	-	-	3,321
16	0.577			5,563	-	-	3,208
17	0.557			5,563	-	-	3,100
18	0.538			5,563	-	-	2,995
19	0.520			5,563	-	-	2,894
20	0.503			5,563	-	-	2,796
21	0.486			5,563	-	-	2,701
22	0.469			5,563	-	-	2,610
23	0.453			5,563	-	-	2,522
24	0.438			5,563	-	-	2,436
25	0.423			5,563	-	-	2,354
26	0.409			5,563	-	-	2,274
27	0.395			5,563	-	-	2,198
28	0.382			5,563	-	-	2,123
29	0.369			5,563	-	-	2,051
30	0.356			5,563	-	-	1,982
31	0.346			5,563	-	-	1,924
32	0.336			5,563	-	-	1,868
33	0.326			5,563	-	-	1,814
34	0.317			5,563	-	-	1,761
35	0.307			5,563	-	-	1,710
36	0.298			5,563	-	-	1,660
37	0.290			5,563	-	-	1,612
38	0.281			5,563	-	-	1,565
39	0.273			5,563	-	-	1,519
40	0.265			5,563	-	-	1,475
41	0.257			5,563	-	-	1,432
42	0.250			5,563	-	-	1,390
43	0.243			5,563	-		

Year	Discount factor	E&P	Construction	O&M	PV E&P	PV Construction	PV O&M
44	0.236			5,563	-	-	1,310
45	0.229			5,563	-	-	1,272
46	0.222			5,563	-	-	1,235
47	0.216			5,563	-	-	1,199
48	0.209			5,563	-	-	1,164
49	0.203			5,563	-	-	1,130
50	0.197			5,563	-	-	1,097
51	0.192			5,563	-	-	1,065
52	0.186			5,563	-	-	1,034
53	0.181			5,563	-	-	1,004
54	0.175			5,563	-	-	975
55	0.170			5,563	-	-	947
56	0.165			5,563	-	-	919
57	0.160			5,563	-	-	892
58	0.156			5,563	-	-	866
59	0.151			5,563	-	-	841
60	0.147			5,563	-	-	817
61	0.143			5,563	-	-	793
62	0.138			5,563	-	-	770
63	0.134			5,563	-	-	747
64	0.130			5,563	-	-	726
65	0.127			5,563	-	-	704
66	0.123			5,563	-	-	684
67	0.119			5,563	-	-	664
68	0.116			5,563	-	-	645
69	0.112			5,563	-	-	626
70	0.109			5,563	-	-	608
71	0.106			5,563	-	-	590
72	0.103			5,563	-	-	573
73	0.100			5,563	-	-	556
74	0.097			5,563	-	-	540
75	0.094			5,563	-	-	524
76	0.092			5,563	-	-	511
77	0.090			5,563	-	-	499
78	0.087			5,563	-	-	487
79	0.085			5,563	-	-	475
80	0.083			5,563	-	-	463
81	0.081			5,563	-	-	452
82	0.079			5,563	-	-	441
83	0.077			5,563	-	-	430
84	0.075			5,563	-	-	420
85	0.074			5,563	-	-	409
86	0.072			5,563	-	-	399
87	0.070			5,563	-	-	390
88	0.068			5,563	-	-	380
89	0.067			5,563	-	-	371
90	0.065			5,563	-	-	362
91	0.063			5,563	-	-	353
92	0.062			5,563	-	-	344
93	0.060			5,563	-	-	336
94	0.059			5,563	-	-	328
95	0.057			5,563	-	-	320
96	0.056			5,563	-	-	312
97	0.055			5,563	-	-	304
98	0.053			5,563	-	-	297
99	0.052			5,563	-	-	290
					£ 853,460	**£ 3,926,663**	**£ 154,913**

Option Summary

PV Enabling Costs		**£**	**447,051**
PV Preliminary Costs		**£**	**406,410**
PV Construction Costs		**£**	**3,926,663**
Element 1	£	629,190	
Element 2	£	372,409	
Element 3	£	2,066,152	
Element 4	£	425,940	
Element 5	£	15,000	
Element 6	£	97,446	
PV Operation and Maintenance Costs		**£**	**154,913**
Optimism Bias (60%)		**£**	**2,961,022**
Total Cost		**£**	**7,896,059**

Appendix F

Action Screening Methodology

Storage and Floodplain Storage

Storage considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the study area and reducing the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch points which could be dammed such as a restricted point along a valley. Storage areas can be effective either upstream of the risk areas or within the risk area where parks or open areas are located. Floodplain Storage utilises the existing floodplain by increasing its storage capacity. This can be achieved by cross-flow bunds or by woodland creation which has the effect of increasing the floodplain's roughness resulting in higher water levels and therefore storage.

Storage areas are identified by using the most detailed topographical information available. This information can include OS mapping, a national DTM or LiDAR. Storage areas identified within the hydraulic model extents can be modelled in order to quantify the effect. This would involve representing a dam with a control structure and overspill weir. Where the storage area is outside the model extents an estimate as to its effect is achieved by calculated the potential storage volume. This can then be removed from the flood hydrograph at the inflow to the model. The effect can then be quantified. The uncertainty associated with this method is, however, high. Floodplain Storage can be simulated by adding bunds within the 2D mesh of the hydraulic model or by increasing the roughness coefficient. The effect of each can then be quantified.

Direct Defences

Direct Defences refer to physical barriers which prevent water from entering an area such as flood walls, embankments and barrages. As a general rule Direct Defences are kept as far back from the river channel or coast line as possible allowing the floodplain function to remain active. Where this is not possible, due to flood risk receptors being located within the floodplain, Direct Defences are placed around the property boundary to afford it protection. Where space allows flood embankments are used but where space is restricted flood walls are utilised.

Direct Defences can be simulated within a hydraulic model, either as part of the 1D cross sections or within the 2D mesh. The resulting water level due to the restricted floodplain can be quantified along with the residual risk upstream and downstream.

Conveyance and Control Structures

These actions work by either increasing or restricting flow to the effect of reducing water levels to the risk areas upstream or downstream. Examples include a flow diversion channel with removes flow from the watercourse along an alternative route bypassing the risk area. Existing culverts causing a restriction can be replaced with larger ones increasing the flow capacity and reducing flood risk upstream. Other actions such as sluice gates can restrict the flow reducing the flood risk downstream.

Conveyance and control structure actions can be simulated within a hydraulic model. Structures can be represented within the 1D model and diversion channels can be imprinted into the 2D mesh or given its own 1D network.

Appendix G

NFM Opportunities Map

Langholm NFM Opportunities Map

N

Legend

- Overall Catchment
- Floodplain Woodland
- Catchment Woodlands
- Upland Drain Blocking
- In-Stream Structures

Appendix H

Drawings of Structural Options 1, 2 and 3

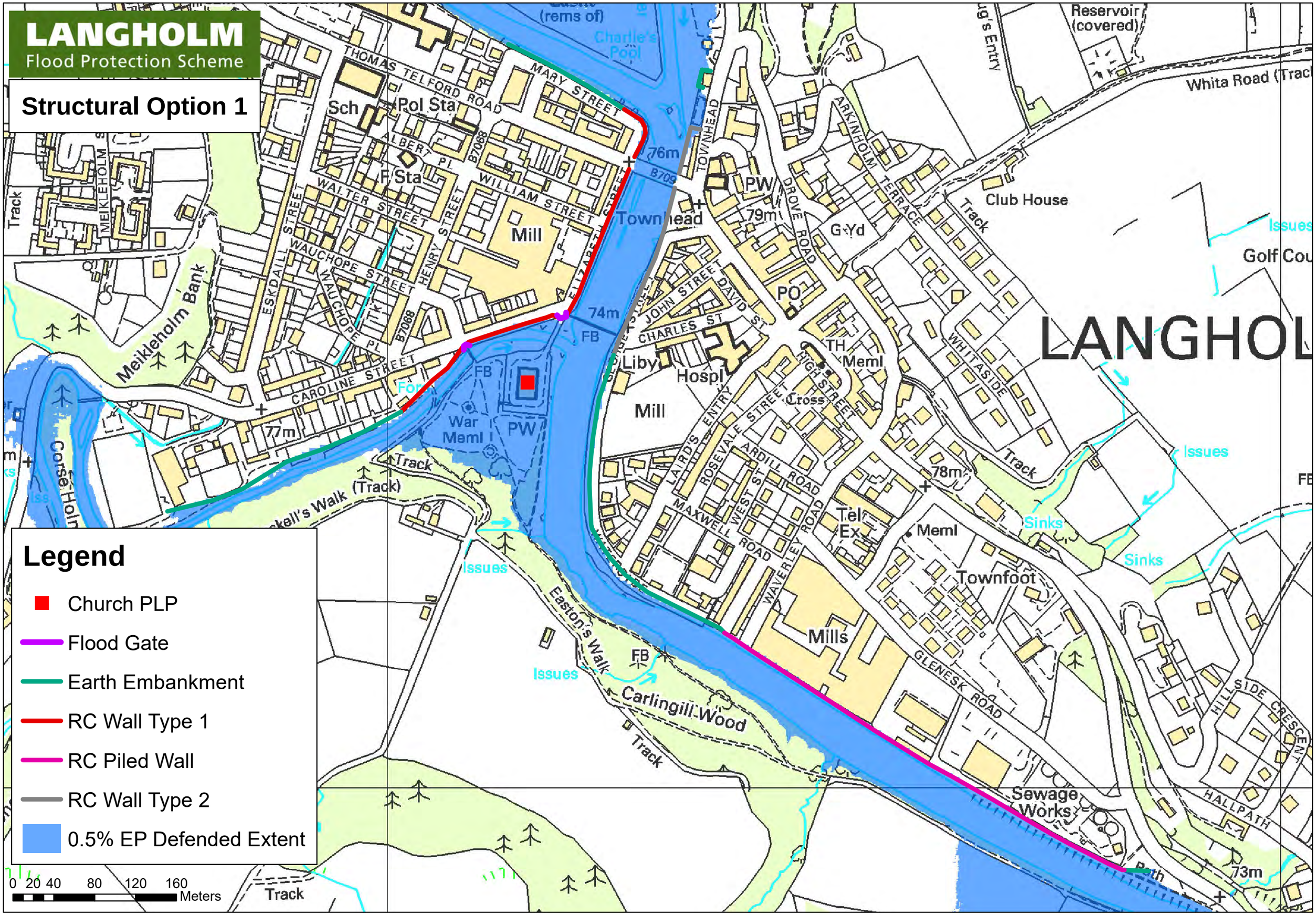
LANGHOLM
Flood Protection Scheme

Structural Option 1

Legend

- Church PLP
- Flood Gate
- Earth Embankment
- RC Wall Type 1
- RC Piled Wall
- RC Wall Type 2
- 0.5% EP Defended Extent

0 20 40 80 120 160 Meters



LANGHOLM
Flood Protection Scheme

Structural Option 2

Landscaped Bypass Channel with Spillweir.

Legend

- Church PLP
- Spillweir
- Bypass Channel
- Earth Embankment
- RC Wall Type 1
- RC Piled Wall
- RC Wall Type 2
- Flood Gate
- 0.5% AEP Defended Extent

0 20 40 80 120 160 Meters

LANGHOLM
Flood Protection Scheme

Structural Option 3

Existing Channel infilled.

Realigned Wauchope Water Channel.

Legend

- Church PLP
- Bypass Channel
- Infilled Channel
- Earth Embankment
- RC Wall Type 1
- RC Piled Wall
- RC Wall Type 2
- 0.5% AEP Defended Extent

0 20 40 80 120 160 Meters

Appendix I

Preferred Option Impact Map

LANGHOLM
Flood Protection Scheme

Preferred Option

Dumfries & Galloway Council

rps MAKING COMPLEX EASY

	Undefended (m^3/s)	Defended (m^3/s)
Flow 1	488	490
Flow 2	149	149
Flow 3	580	584
Flow 4	571	584
Flow 5	105	85
Flow 6	127	130
Flow 7	129	129
Flow 8	629	677
Flow 9	662	677
Flow 10	676	678
	Undefended (m)	**Defended (m)**
W.D.1	4.10	4.10
W.D.2	4.33	4.30
W.D.3	3.84	3.77
W.D.4	1.28	1.23
W.D.5	2.08	2.09
W.D.6	1.93	2.98
W.D.7	5.10	5.10
W.D.8	0.76	0.81
W.D.9	4.41	4.45

W.D. 1
Flow 1
Flow 2
W.D. 2
Flow 3
W.D. 3
Flow 4
Flow 5
W.D. 4
W.D. 6
Flow 6
W.D. 5
Flow 7
Flow 8
W.D. 7
Flow 9
W.D. 8
Flow 10
W.D. 9

Legend

- Level Point
- Flow Point
- Church PLP
- Spillweir
- Bypass Channel

Direct Defence Line (June 2019)

Direct Defence

- Earth Embankment
- RC Wall Type 1
- RC Piled Wall
- RC Wall Type 2
- 0.5% AEP Defended Extent
- Benefitting Area

N

0 20 40 80 120 160 Meters