NEWTON STEWART FLOOD PROTECTION SCHEME – SUPPORTING DOCUMENT
FLOOD MANAGEMENT OPTIONEERING REPORT

FINAL
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SWECO UK LIMITED

Change list

VER.	DATE	CHANGE CONCERNS	ORIGINATOR	REVIEWED	APPROVED
1	07/08/17	DRAFT FOR COMMENT	JK	DRL	DRL
2	25/08/17	UPDATED FOLLOWING COMMENTS	JK	JPF	DRL
3	14/12/17	UPDATED FOLLOWING VM2 MEETING	JK	JPF	DRL
4	14/08/18	UPDATED FOR FLOOD ORDER SUBMISSION	JK	JPF	DRL
5	03/12/18	UPDATED WITH CLIENT COMMENTS	ARW	MT	MT
6	17/04/20	UPDATED WITH CLIENT COMMENTS	JK	ARW	ARW
7	12/05/23	UPDATED TO ADD FLOOD GATES	AD	DCE	GA

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Summary

Newton Stewart was identified as a Potentially Vulnerable Area (PVA) by the Scottish Environmental Protection Agency (SEPA) in their national Flood Risk Management Strategies (FRMS). Newton Stewart sits within the Solway Local Plan District (PVA 14/12). Further need for intervention has been highlighted by several recent and severe flood events.

The FRMS placed an action on Dumfries and Galloway Council to reduce the risk of flooding to properties in Newton Stewart from the River Cree. In response to the FRMS Dumfries and Galloway Council produced a Local Flood Risk Management Plan (LFRMP) in which they committed to the actions placed on them by SEPA. Subsequently Sweco has investigated the benefits of various flood protection measures for Newton Stewart, culminating in the submission of a Flood Protection Order (FPO). Prior to Sweco's engagement, Dumfries and Galloway Council had already identified that the Sparling Bridge exacerbated flood risk. As a result, the relocation of the Sparling Bridge from its previous location to a higher elevation is inherent in all options considered.

This report has been submitted with the FPO as supporting evidence, and details the optioneering process undertaken by Sweco on behalf of Dumfries and Galloway Council. In Chapter 2, the report presents the long-list options with the associated consultation and decision-making process. Results of the long list assessment were presented to stakeholders at Value Management Meeting 1, noted in Section 1.5. Discussion took place to reach consensus as to whether an option should progress to the short-list. The preferred option, presented in the final chapter, was identified by Dumfries and Galloway Council and Stakeholders at Value Management Meeting 2.

The preferred option is a combination of options presented in chapter 2, with the addition of the relocation of the Sparling Bridge, and consists of:

- re-location of the Sparling Bridge to a higher elevation;
- direct defences through the main town including use of flood gates (*option 6);*
- reprofiling of land beneath A75T bridge (*option 7); and*
- reprofiling of land around the pumping station (*option 24).*

Further details and information on the Preferred Options can be found in the supporting document "*Flood Management Preferred Option and Economic Appraisal Report*".

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List of Common Phrases

Attenuate/Attenuation: The action of reducing a flood peak which still permits the same volume of water to pass, but across a longer period of time.

Confluence: The location where two or more rivers meet.

Flood Relief Culvert: A pipe designed to convey flood water from one location to another, often through or under a man-made structure or obstructing geographical feature.

Flood Study: An investigation into the causes of flooding, concluding with potential options for mitigation.

Hydrological Assessment: A statistical estimation of the flows in a river using either available past data or a set of information ('descriptors') about the catchment.

In-Line Impoundment: A weir, dam or other structure in the river designed to hold water back and regulate the flow from upstream to downstream.

Multi-Criteria Assessment: A method by which possible options are scored using set criteria to allow for fair comparisons of their merits.

Off-Line: Not on the main river channel, generally next to it and often connected to the river.

Optioneering: The process of reducing the number of potential options to conclude a preferred option (or, set of options).

Return Period: The statistical recurrence interval. For example, the 1 in 200 year (sometimes written 1:200 year) return period is the 0.5% probability that an event will occur in any given year.

Upstream Storage: Storage of water in the catchment upstream of a town (normally via an impoundment either on- or off-line) with the intention of causing flow attenuation to reduce the impact of extreme flood events.

Whole-Life Cost: The total cost of a proposed scheme, inclusive of the design; capital cost of construction; construction overhead costs; land purchase; service diversion; lifetime (normally 100 years) maintenance and inspection; and mid-life refurbishment (where applicable).

List of Abbreviations

CVCC: Cree Valley Community Council

DGC: Dumfries & Galloway Council

FRMS: Text

LFRMP: Text

NFM: Natural Flood Management

PVA: Potentially Vulnerable Area

SEPA: Scottish Environment Protection Agency

SFRA: Text

SNH: Scottish Natural Heritage

SSSI: Site of Special Scientific Interest

1 Introduction

Sweco, appointed by Dumfries & Galloway Council, have designed a Flood Protection Scheme for the town of Newton Stewart. Kaya Consulting, having undertaken the original flood study, were retained on the project to provide hydraulic modelling services. This document sets out the process followed to arrive at the preferred option. Prior to Sweco's engagement, Dumfries and Galloway Council had already identified that the Sparling Bridge exacerbated flood risk. As a result, the relocation of the Sparling Bridge from its previous location to a higher elevation is inherent in all options considered.

1.1 Background to Project

A Strategic Flood Risk Assessment (SFRA) was carried out by Dumfries & Galloway Council in 2007, highlighting Newton Stewart as a priority. The River Cree and Penkiln Burn flow through the towns of Newton Stewart and Minnigaff, which are situated adjacent to each other and can be seen on a location plan in Figure 1-1.

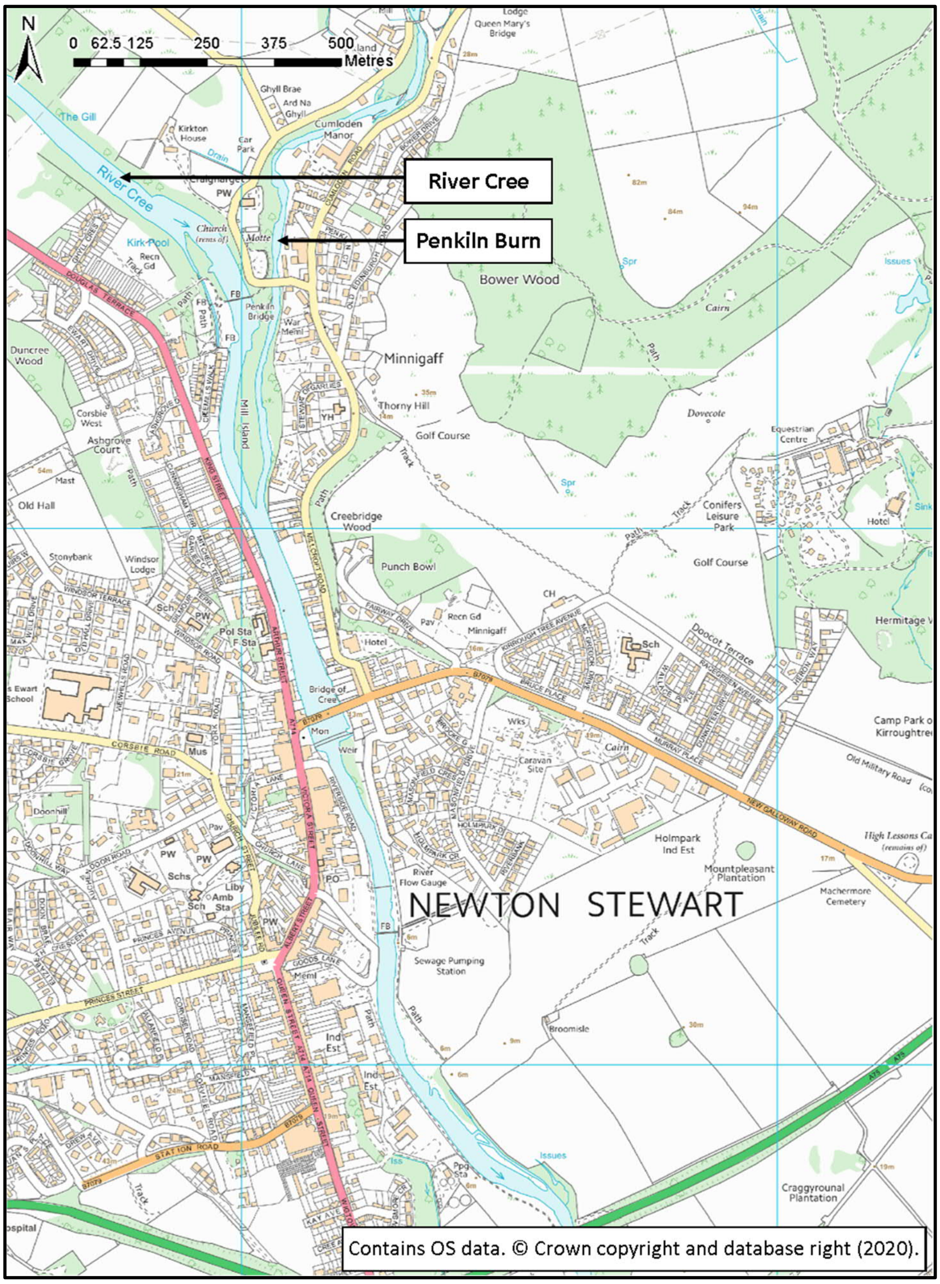

Figure 1-1 – Newton Stewart and Associated Watercourses

In 2015 Newton Stewart was identified as a Potentially Vulnerable Area (PVA) by SEPA in their national Flood Risk Management Study (FRMS) (PVA 14/12). The FRMS placed an action on Dumfries and Galloway Council to reduce the risk of flooding to properties in Newton Stewart from the River Cree. In response to the FRMS, Dumfries and Galloway Council published the Solway LPD Local Flood Risk Management Plan (LFRMP) in June 2016. The plan details the actions and the timeline to deliver the goals set out in the FRMS should be carried out.

Since 2001, Dumfries & Galloway Council have recorded eleven fluvial flood incidents from these watercourses within the towns. Of these incidents two were considered major, one in 2012 and the other in 2015, resulting in severe damage and requiring widespread response from the emergency services. The community have commented that these large flood events have now had a negative impact on the town over the longer term.

1.2 Previous Reports

Kaya Consulting carried out a Flood Study for Newton Stewart in 2015[1]. The study outcomes were based on a 1D-2D hydraulic model, constructed in Flood Modeller Pro. Several flood mitigation measures were proposed, one of which was the relocation of the Sparling Bridge within the town to a higher elevation. An update to the report was provided in May 2017[2], to account for an updated hydrological assessment and in response to the major flooding event of 2015. Dumfries and Galloway Council consulted extensively with the community regarding the new location and arrangement for the bridge. Sweco have developed the final design of the new bridge on behalf of the council, and in partnership with Sustrans and the Cree Valley Community Council.

1.3 Design Brief

The design brief was to produce a scheme that: (i) protects as much of the town as is practical; and (ii) attract Scottish Government funding for its construction. The brief required a wide range of considerations, including: technical feasibility; economic viability; environmental impacts; and the views of the local community.

1.4 Optioneering Process

The optioneering process has been shown graphically in Figure 1-2. Initially, a long-list of potential options was generated, including options noted in previous Kaya Consulting reports, and options suggested by the local community. The long list was assessed for feasibility at a high-level, and the relevant stakeholders were consulted prior to a short-list being formed.

Detailed consideration of the options within the short-list has taken place to gain an understanding of the practicality of each potential option. Economic appraisal of each short-

[1] Newton Stewart Flood Study 22 April 2015, Kaya Consulting Ltd
[2] Addendum 23 May 2017, Kaya Consulting Ltd

list option has also taken place. This has facilitated a cost-benefit analysis to assist in the identification of the preferred option.

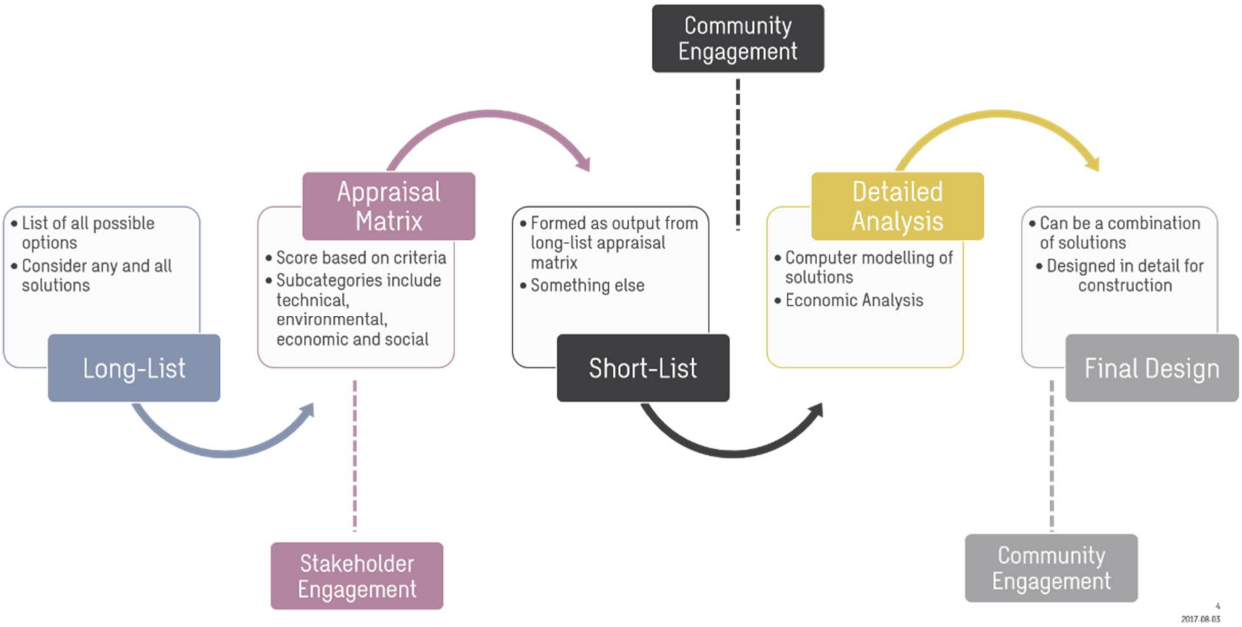

Figure 1-2 – Optioneering Process

1.5 Consultation and Engagement

Consultation with the relevant stakeholders and engagement with the local community forms an essential part of the optioneering process. Two Value Management Meetings (VM) were held in Dumfries – the first on 1 August 2017 and the second on 7 November 2017. All of the following parties and key stakeholders were invited to both meetings.

- **Scottish Environment Protection Agency (SEPA):** SEPA provided advice on works that may be carried out within the river and on environmental considerations. SEPA attended the VM1 meeting. A meeting was held with SEPA (on 28 November 2017) following the VM2 meeting to the discuss analysis of short-list options and the chosen preferred solution.
- **Scottish Natural Heritage (SNH):** SNH provided advice on biodiversity and ecosystems. SNH attended the VM2 meeting.
- **Scottish Water:** Scottish Water have network assets that interact with the River Cree, and works relating to flood prevention could have an impact on this network. Scottish Water attended the VM2 meeting.
- **Forestry Commission Scotland:** The Forestry Commission are responsible for a large area of forest in the upper Cree catchment. The Forestry Commission attended both VM meetings.
- **Royal Society for the Protection of Birds (RSPB):** The RSPB advised on any options that could impact bird species in the local area and within the catchment. The RSPB attended the VM1 meeting, however declined attendance at the VM2 meeting due to the low impact the short-list options would have on their area of interest.
- **Galloway Fisheries:** Galloway fisheries advised on fishing activity that takes place on the River Cree and Penkiln Burn. Furthermore, several protected species are known to be present in the area. Galloway Fisheries attended both VM meetings.

- **Kaya Consulting:** Kaya Consulting carried out flood studies in the area and are continuing to provide hydraulic modelling services for this study. They attended both VM meetings..
- **Cree Valley Community Council (CVCC):** The CVCC represent the views of the local community and the Cree Valley Flood Action Group. The CVCC were present at all public engagement events and had representatives at both VM meetings.
- **Elected Members:** Local Elected Members represent the views of the community and provide further means to engage with local people. Two local Elected Members attended the VM1 meeting, and three local Elected Members attended the VM2 meeting.

1.6 Community Engagement

Two community engagement events were held in Newton Stewart to inform and involve the local people in the developing options for the Flood Protection Scheme. The first public engagement event was held over three days from 30 November to 2 December 2017 to provide an update on the different options being considered as part of the ongoing scheme. The second event, held over a further three days from 21 June 23 June 2018, provided details of the preferred options. The full engagement process is contained within the Community Consultation Report.

2 Long-List Options

This section presents the 24 ‘long list’ options, 19 of which were put forward by Sweco and Kaya Consulting, and a further 5 options put forward by CVCC. Results of the assessment were presented to the stakeholders at the VM1 meeting, noted in Section 1.5. Discussion took place to reach consensus as to whether an option should progress to the short-list.

2.1 Multi-criteria Assessment Process

Long list options were assessed using a ranking matrix. This assessment considered a total of 29 assessment criteria divided into 4 areas: technical, economic, environmental and social. Each assessment criterion was assigned a weighting in the range 1-5. The 4 areas were also weighted to provide preference to the technical and economic areas that are key to the realisation of the project. Each of these areas has been expanded on in this section of the report. Areas where major problems were identified were classified as a ‘fail’ to discount options in the event of an unacceptable issue being identified under any of the 28 assessment criteria. The 4 areas and 28 assessment criteria are noted in the following sub-sections.

2.1.1 Technical

The criteria that were grouped under area ‘Technical’ were given a weighting of 35% to reflect the importance of technical feasibility. The assessment criteria used in this part of the ranking matrix were:

- condition of existing assets;
- flood damage reduction;
- spatial constraints;
- topographic constraints;
- vegetation density;
- health & safety during construction; and
- buildability.

2.1.2 Economic

Criteria grouped under area ‘Economic’ were assigned a weighting of 35% to reflect the importance of economic benefit. The assessment elements used in this part of the ranking matrix were:

- site access;
- ground conditions;
- land ownership;
- impact upon development potential;
- flood damage reduction; and
- preliminary whole-life costing.

2.1.3 Environmental

Criteria group under area ‘Environmental’ were assigned a weighting of 15%. The lower weighting reflects that: (i) undesirable environmental scores are relatively easily mitigated; and (ii) environmental scores that would result in overall objection to the scheme from statutory authorities are marked as an overall ‘fail’. The assessment elements used in this part of the ranking matrix were:

- flood risk susceptibility;
- impact on recreational users;
- ecology and designated sites;
- heritage sites;
- water quality impacts;
- biodiversity;

- climate change resilience;
- air quality impact and carbon footprints;
- air quality impact (post-construction);
- controlled activities regulations; and
- carbon emissions.

2.1.4 Social

Criteria grouped under area 'Social' were assigned a weighting of 15%. The lower weighting was selected to reflect the comparative ease of mitigating social effects. The assessment elements used in this part of the ranking matrix were:

- public safety (operation);
- stakeholder issues;
- proximity to urban areas; and
- indirect benefits.

2.2 Option 1: Upstream Storage at Glenhapple

This option sought to attenuate flow in the upper catchment, as shown in Figure 2-1.

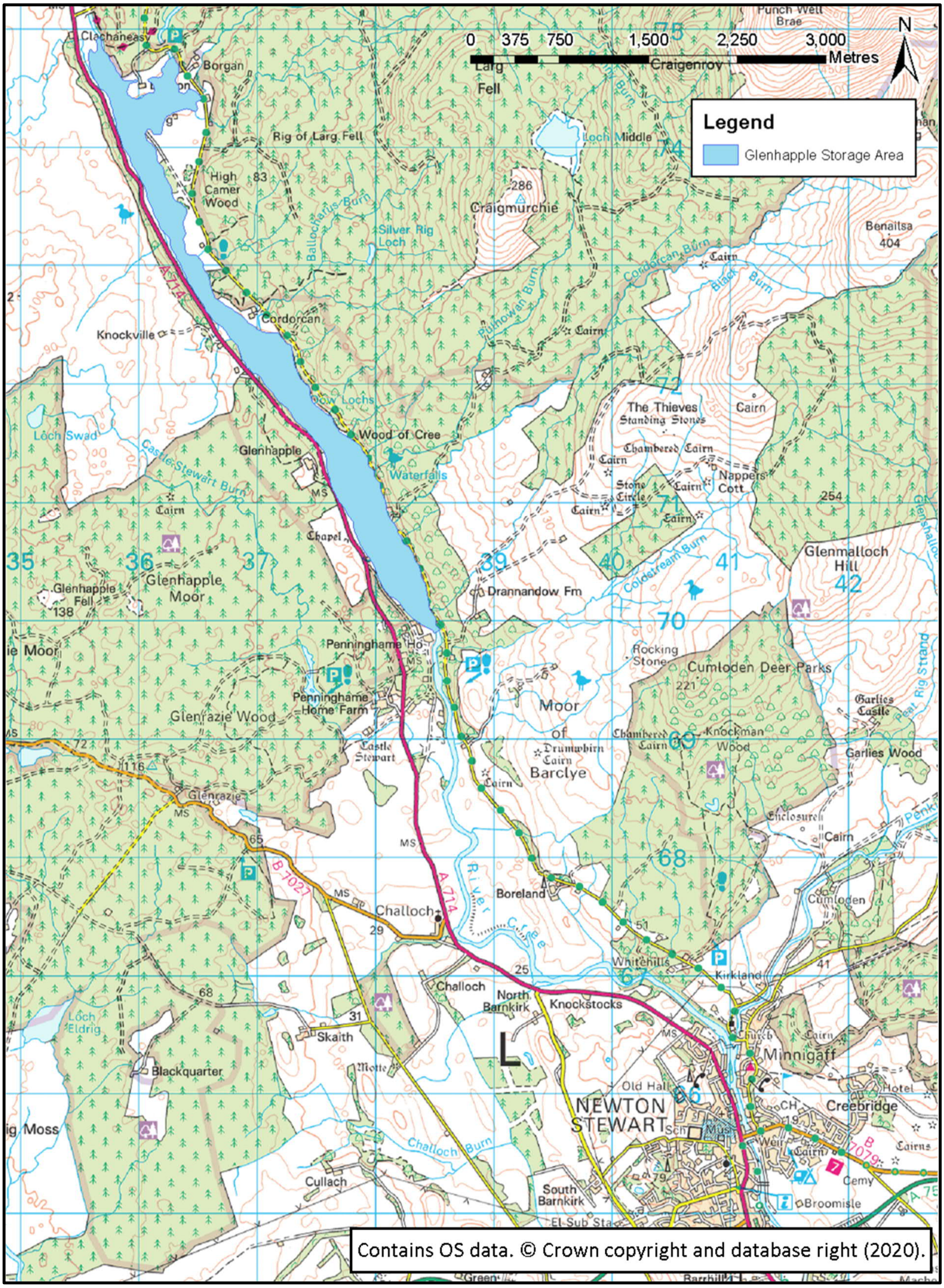

Figure 2-1 - Upstream Storage at Glenhapple

2.2.1 Background

This option was considered during the original 2015 Kaya Consulting study, which identified a potential upstream storage area near to Glenhapple. This area was estimated to provide around 2 million m^3 of storage volume within the upper catchment. An initial modelling assessment has found that this would likely only be effective up to the 1:75 year return period.

2.2.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option are provided in Table 2-1. The option scored highly on technical, due to simple impoundment design requirements. The option scores poorly for economic (due to high costs) and environmental (due to in-line impoundment). The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-1 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
63%	22%	25%	69%	**44%**

2.2.3 Feedback from Stakeholders

Galloway Fisheries questioned the impact of the scheme on protected fish species, which all have their main spawning areas upstream of Glenhapple. It was noted that a fish ladder would be incorporated into any design here.

SEPA expressed preference that other opportunities were considered before they would be happy with an on-line storage area.

Further discussions at the VM1 meeting with stakeholders formed the conclusion that this option would be unlikely to solve the problem on its own, and therefore the cost-benefit ratio was considered to fall into a range too low to achieve Scottish Government funding.

2.2.4 Decision

This option did not proceed to the short-list. This was due to initial modelling from Kaya Consulting showing that the likely effect on flood risk in the town was not significant, combined with the likely cost and complexity of dam construction in the upper catchment.

2.3 Option 2: Upstream Storage at Linloskin Bridge

This option sought to attenuate flow in the upper catchment as shown in Figure 2-2.

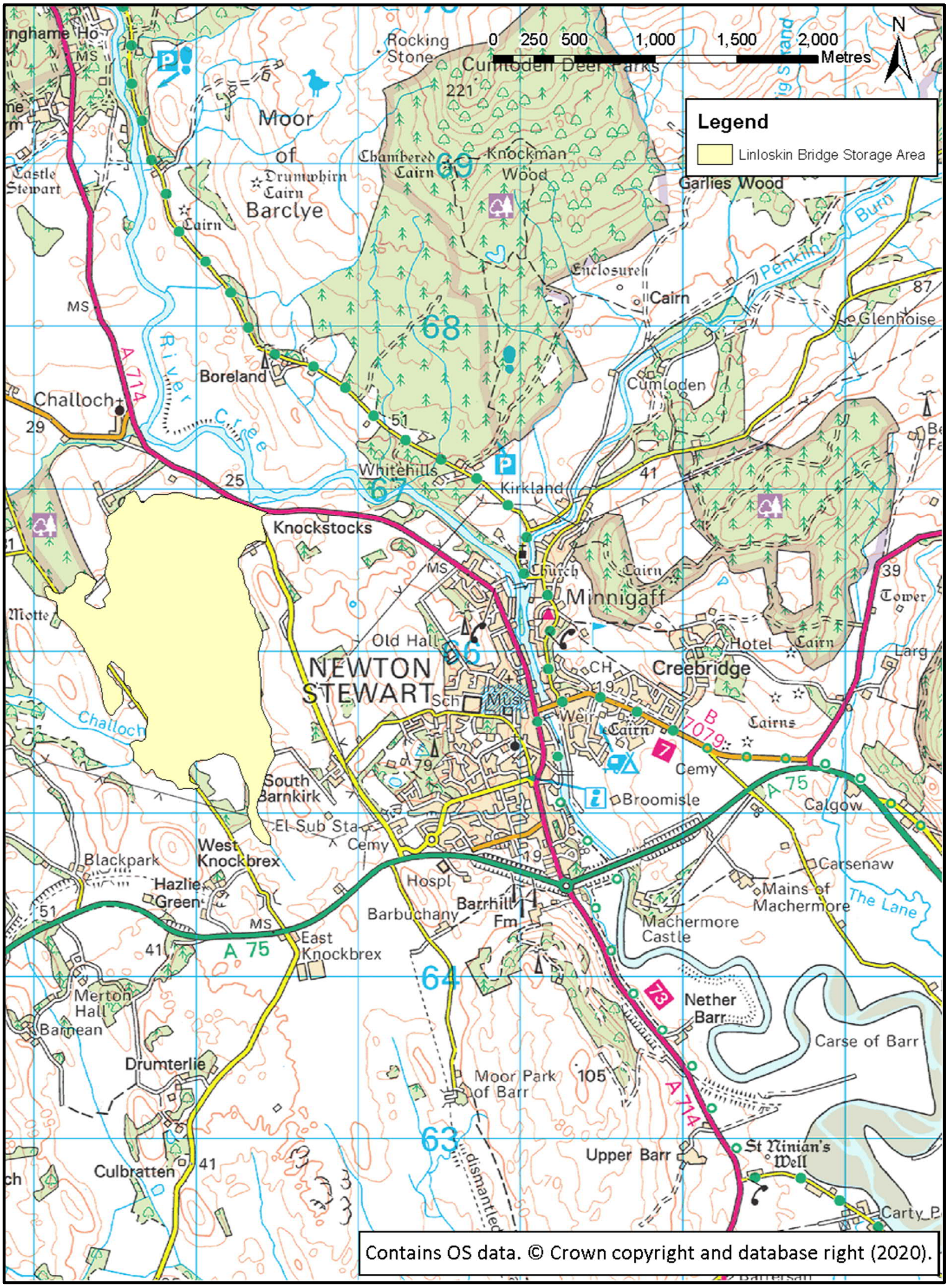

Figure 2-2 - Upstream Storage at Linloskin Bridge

2.3.1 Background

This option was considered because the local topography could provide 3 million m^3 of upstream storage. This volume was situated on a tributary of the River Cree (Challoch Burn), although it is envisaged that a diversion from the Cree into this area may be possible. An existing road embankment separates this area from the River Cree, and a flow restriction beneath this road would be needed to impound water within the area.

2.3.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option are provided in Table 2-2. The option scored lower on economic criteria due to the volume of land-take required near the town. The environmental score was greater that option 1 as the smaller land-take would have lesser impact on local ecology. The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-2 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
52%	15%	50%	69%	**41%**

2.3.3 Feedback from Stakeholders

SEPA spoke more favourably on this type of option, as the storage is ‘off-line’. Galloway Fisheries also commented that this would be preferred for them in comparison to ‘on-line’ storage as there would be minimal impact on fish species.

Discussion at the VM1 meeting concluded that this may have some impact on flood reduction despite being a smaller area that Glenhapple. Further modelling would be required to assess this impact.

2.3.4 Decision

This option was taken forward to the short-list. Further hydraulic modelling has been completed by Kaya Consulting to ascertain likely effects of this option on flood risk within the town, results have been presented in Section 3.1.

2.4 Option 3: Upstream Storage at Frankie Hill

This option sought to attenuate flow in the upper catchment as shown in Figure 2-3.

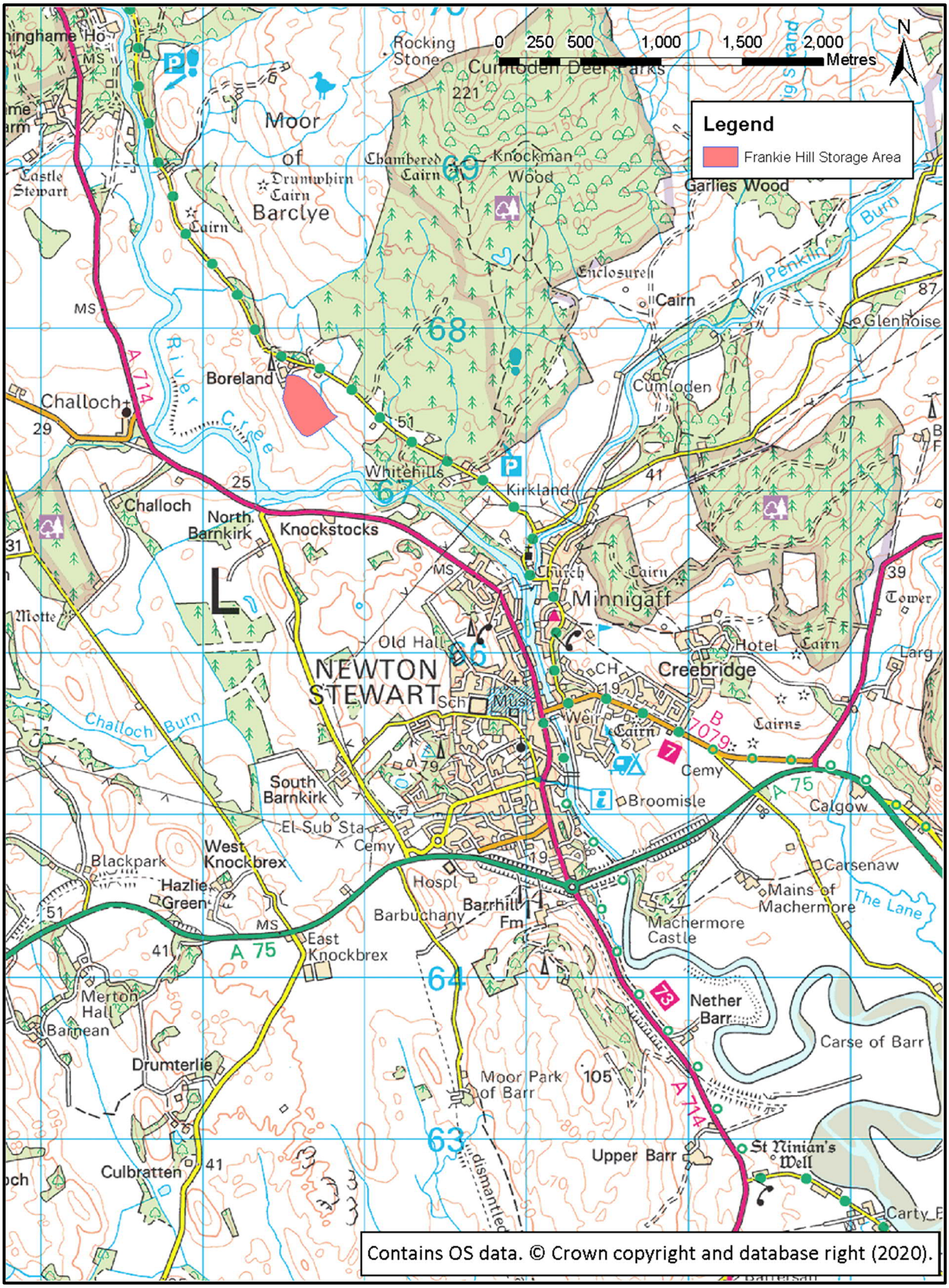

Figure 2-3 - Upstream Storage at Frankie Hill

2.4.1 Background

This option provides around 200,000 m^3 of storage near Frankie Hill, in the Boreland area upstream of Newton Stewart. The storage area is situated on an unnamed tributary to the River Cree. A small dam structure would need to be constructed to impound water within this area.

2.4.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option are provided in Table 2-3. The option scores lower than the option at Linloskin Bridge for technical due to the lower storage volume available. Economic criteria score higher as there is less impact on private landowners. The overall score for this option placed it approximately within the middle of all the ranked long list.

Table 2-3 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
37%	23%	50%	69%	**41%**

2.4.3 Feedback from Stakeholders

Kaya Consulting estimated that this would only reduce flows within the town by around 10 m^3/s, which is a negligible reduction in the context of flood risk management.

Further discussion at the VM1 meeting identified that this option would need to be constructed across two tributaries significantly increasing the cost. A consensus was reached that option 2 would be a preferred over option 3.

2.4.4 Decision

This option did not proceed to the short-list. The primary reason for this was that the storage volume was low and would likely have minimal to no effect on flood risk within the town.

2.5 Option 4: Installation of Obstructions on River Cree

This option sought to attenuate flow along the length of the river channel as shown in Figure 2-4.

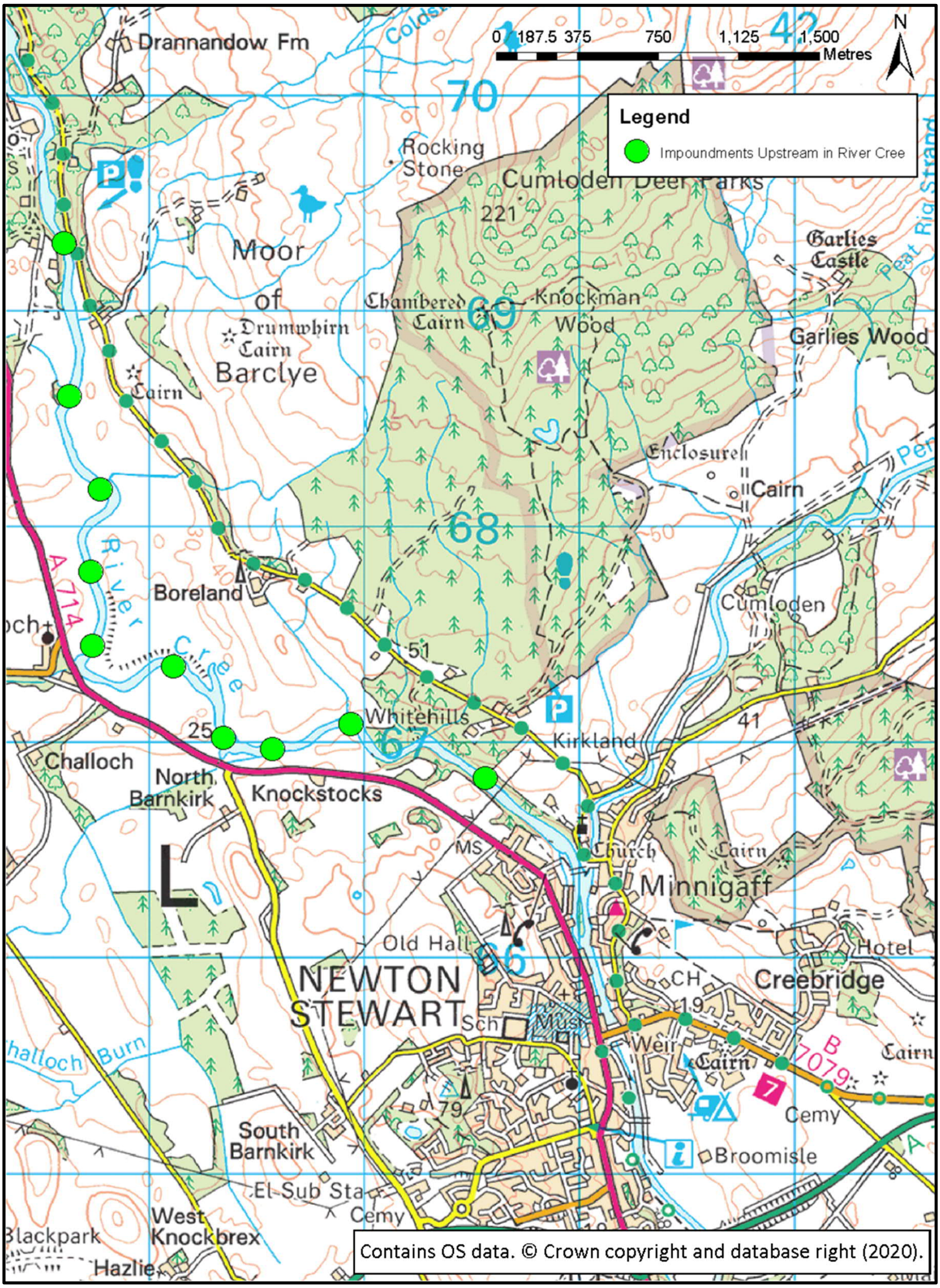

Figure 2-4 - Possible Locations for Obstructions on the River Cree

2.5.1 Background

A series of upstream obstructions on the River Cree were investigated. These would take the form of weirs within the channel, each holding a small volume of water back. These weirs would be around 1m in depth, although a range of sizes were considered.

2.5.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option are provided in Table 2-4. This option scored higher on the technical and economic aspects compared with other storage options due to its likely high impact at low return periods for relatively low cost. However, this option was found to be less effective at higher return periods. The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-4 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
59%	50%	43%	88%	**57%**

2.5.3 Feedback from Stakeholders

Kaya Consulting was asked to model this option ahead of the VM1 meeting and came with the conclusion that it would likely only reduce flood water levels at the 1:200 year return period by around 5-10%.

Galloway Fisheries have stated that this option has issues for them, due to the potential for erosion and impediment to fish passage. SEPA echoed the concerns of Galloway Fisheries.

2.5.4 Decision

This option was taken forward to the short-list. Additional hydraulic modelling at lower return periods (1:200 year already modelled) was conducted, with results presented in Section 3.2.

2.6 Option 5: Installation of Obstructions on Penkiln Burn

This option sought to attenuate flow along the length of the burn, as shown in Figure 2-5.

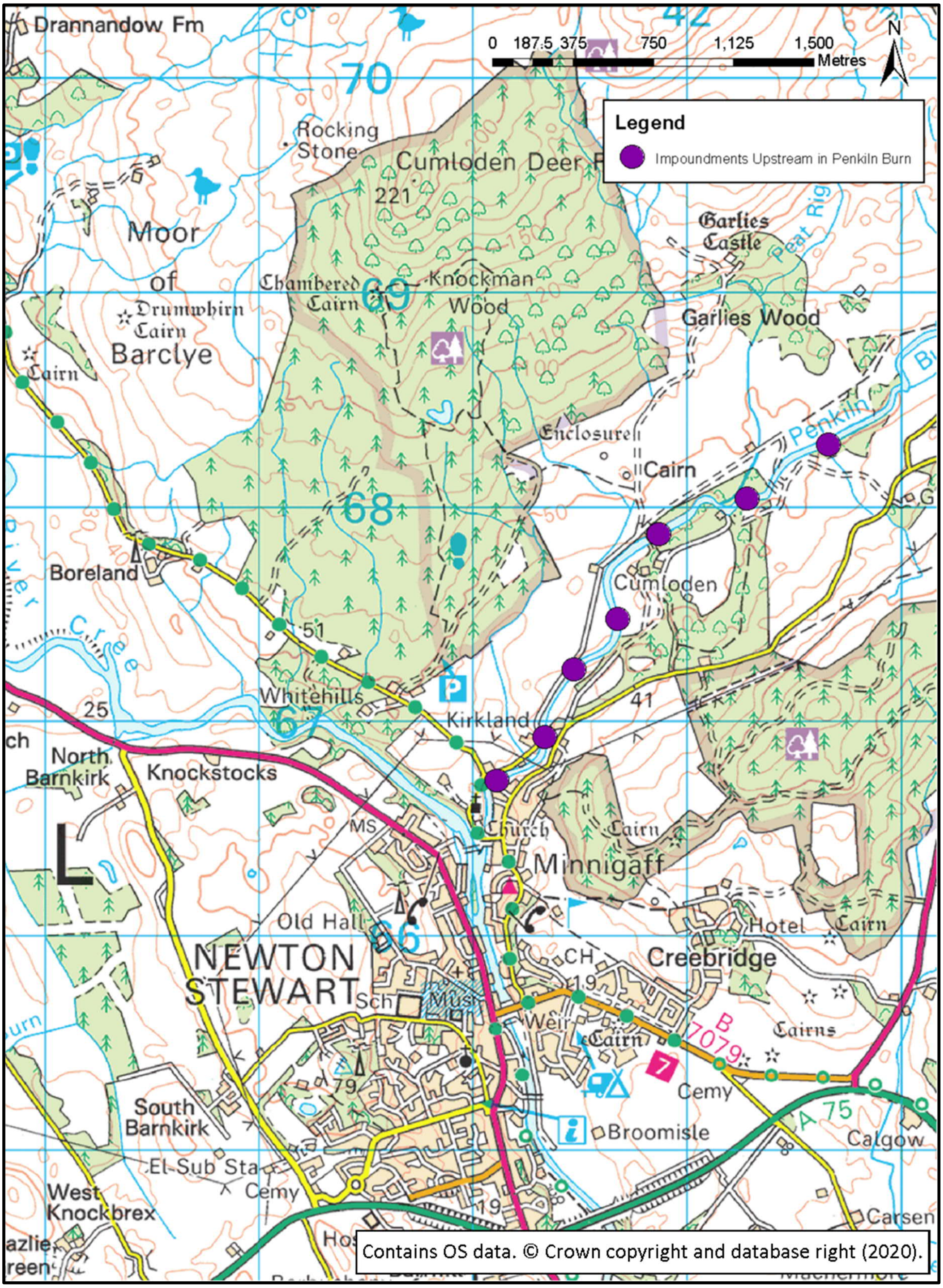

Figure 2-5 - Possible Locations for Obstructions on the Penkiln Burn

2.6.1 Background

Similar to Option 4, a series of obstructions on the Penkiln Burn upstream of the town were considered. These would take the form of weirs within the channel, each holding a small volume of water back.

2.6.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option are provided in Table 2-5. This option failed the assessment based on constructability, in light of difficult access requirements and overall restricted working space.

Table 2-5 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
FAIL	35%	48%	88%	**FAIL**

2.6.3 Feedback from Stakeholders

The consensus reached at the VM1 meeting is that this option would likely have minimal impact due to the relatively small proportion (approx. 15%) of flows towards the town originating in the Penkiln Burn.

2.6.4 Decision

This option did not proceed to the short-list. The reason for this was the low proportion of flows entering the town from the Penkiln Burn (approximately 15% of total flows), meaning that interventions here were likely to have minimal to no impact on flood risk.

2.7 Option 6: Construction of Direct Defences including use of flood gates

This option sought to hold flow within the river, as shown in Figure 2-6.

Figure 2-6 - Potential Area of River for Direct Defences

2.7.1 Background

Direct defences include barriers - walls or embankments and can be used in conjunction with other interventions. Direct defences can offer opportunities to regenerate riverside areas. At this stage no specific location for direct defences was considered.

2.7.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-6. This option scored highly overall, aided by the likely effectiveness in reducing flood levels while at the same time being a relatively low-cost option. The score for social was lower due to the need to construct within the town itself. The overall score for this option placed it high in the ranked long list (>60%).

Table 2-6 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
66%	78%	45%	38%	**63%**

2.7.3 Feedback from Stakeholders

CVCC noted in a letter to DGC, ahead of the VM1 meeting, that this option was a high preference in order to protect the commercial heart of the town. There was consensus among stakeholders at the VM1 meeting that there was an inevitability that some form of direct defences would be required.

2.7.4 Decision

This option was taken forward to the short-list. Discussion highlighted that direct defences will be required in some way, possibly in combination with other options. Further modelling has been carried out, with results presented in Section 3.3.

2.8 Option 7: Increase Flow Area Beneath A75T Bridge

This option sought to take water away from the town more quickly, as shown in Figure 2-7.

Figure 2-7 - A75T Bridge Location

2.8.1 Background

This option was considered during the original 2015 Kaya Consulting study, which identified scope to increase the width of the channel beneath the bridge carrying the A75T over the River Cree. At this location, the embankment for the A75T crosses the floodplain of the River Cree, resulting in a barrier to flow. Increasing conveyance at this point would result in less backing-up of flow, reducing water level in the town.

2.8.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-7. Scores for the option were relatively low, partly due to complexities associated with a nearby Site of Special Scientific Interest (SSSI) and removal/relocation of amenity in the local area during construction. The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-7 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
49%	56%	46%	34%	**49%**

2.8.3 Feedback from Stakeholders

CVCC noted, in a letter to DGC ahead of the VM1 meeting, that either this option or option 9 should be taken into consideration as they feel the embankment effectively dams the natural floodplain.

Galloway Fisheries noted that this is a spawning location, and downstream of the A75T crossing is a SSSI. Any work within the river here should take spawning into account.

Further discussion noted that while the option would remove a social amenity (path/cycle path), the scheme design would likely be able to replace this amenity in a similar location so that there was no overall loss.

Kaya Consulting previously carried out some modelling in the area which indicated benefits were localised and consequently not effective at reducing flood risk in the urban areas upstream. It was agreed that further work could be completed to provide a more detailed insight to the potential impacts.

2.8.4 Decision

This option was taken forward to the short-list. Further hydraulic modelling was carried out, with results presented in Section 3.4.

2.9 Option 8: Removal of A75T Embankment

This option sought to take water away from the town more quickly, as shown in Figure 2-8.

Figure 2-8 - A75T Embankment Location

2.9.1 Background

As highlighted in the background for Option 7, the A75T embankment was constructed on the floodplain of the River Cree and acts as a barrier to out-of-bank flow. This results in backing-up of flows from this location towards the town. While water does not back-up on the floodplain to inundate the town directly from here, the feature is likely responsible for raising water levels upstream.

2.9.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-8. Scores for the option were low due to the high cost of embankment removal and associated disruption to the local traffic network. The overall score for this option placed it within those which scored the lowest (<40%).

Table 2-8 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
35%	21%	35%	84%	**37%**

2.9.3 Feedback from Stakeholders

Kaya Consulting carried out modelling work on this proposed intervention, it was found that removing the embankment did not have a significant impact on flood levels further upstream but did provide local benefit to water levels.

A representative of the Community Council noted that there were effects seen downstream of the bridge since the construction of the A75T. This has been in the form of an altered sediment erosion/deposition regime.

2.9.4 Decision

This option did not proceed to the short-list. This was due to the high complexity and likely high cost of completely removing and replacing the embankment, as well as the associated disruption to the town implementation of the option would likely cause.

2.10 Option 9: Increase A75T Flood Relief Culvert Size/Numbers

This option sought to take water away from the town more quickly, as shown in Figure 2-9.

Figure 2-9 - Flood Relief Culverts Beneath A75T

2.10.1 Background

Existing flood relief culverts are present beneath the A75T embankment, on the western bank of the river. These culverts are ineffective at present due to their condition and due to poor drainage pathways towards them from the River Cree. Increasing the size and number of these culverts; and creating provision for water to efficiently reach and pass through them has been considered here.

2.10.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-9. Scores for the option were relatively high due to the low cost of providing culverts; although the effectiveness of this option would require further detailed modelling to be fully understood. The overall score for this option placed it approximately within the middle of all the considered options.

Table 2-9 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
55%	65%	45%	69%	**59%**

2.10.3 Feedback from Stakeholders

CVCC noted, in a letter to DGC ahead of the VM1 meeting, that either this option or option 7 should be taken into consideration as they feel the embankment effectively dams the natural floodplain.

Discussion at the VM1 meeting suggested that the current flood relief culvert system was not working well. It was considered that upgrading them, and finding improved flow paths was likely a useful low-cost solution; although could not be considered alone.

2.10.4 Decision

This option was taken forward to the short-list. It was felt that this would at least contribute to lowering water levels at the town if implemented well. Further hydraulic modelling of this option was carried out, with results presented in Section 3.5.

2.11 Option 10: Removal of Gravel Berm

This option sought to improve in-bank storage, as shown in Figure 2-10.

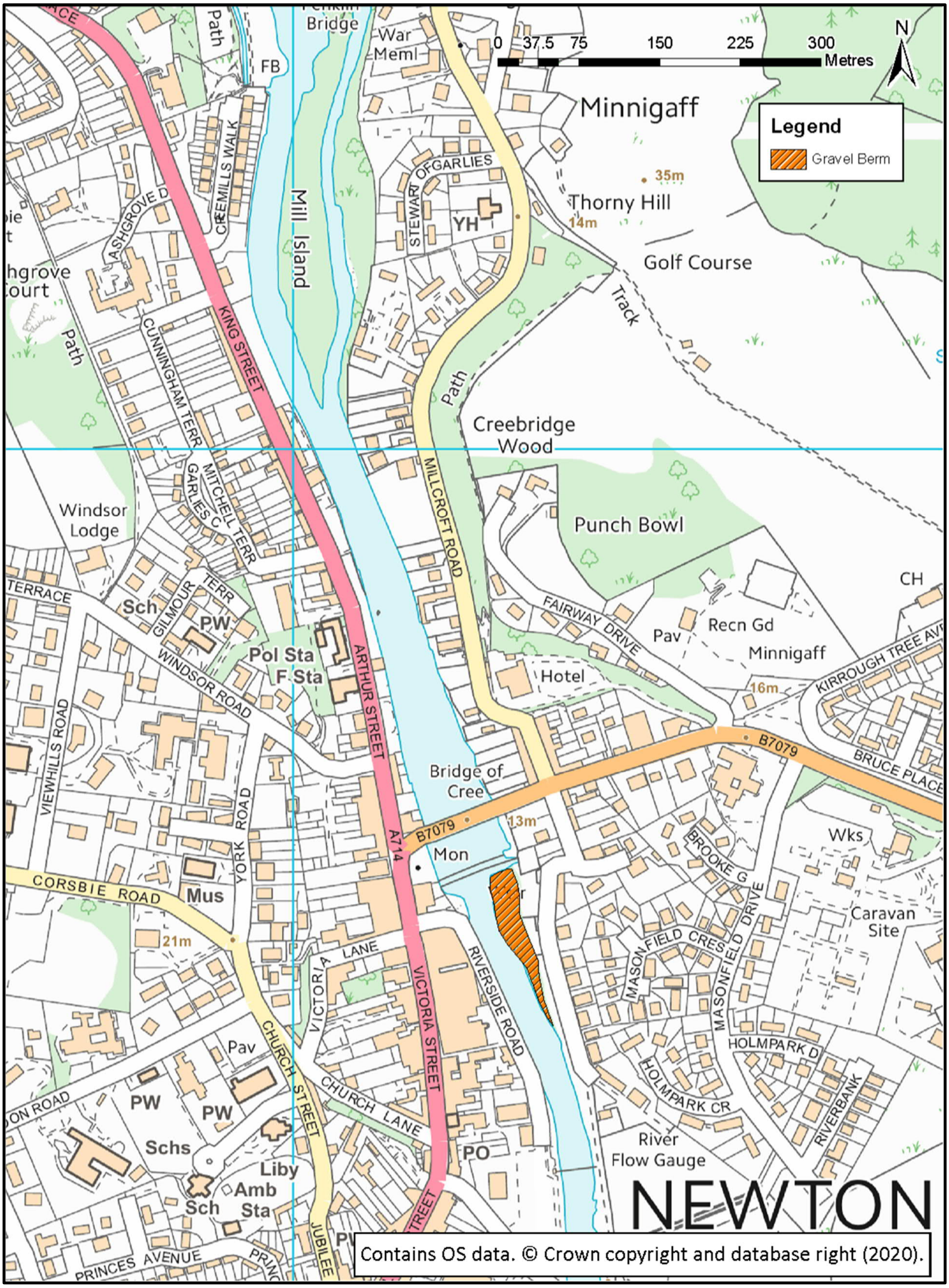

Figure 2-10 - Gravel Berm

2.11.1 Background

An area of high deposition exists immediately downstream of the in-line weir within the town centre. This has, over time, become an island that is now vegetated. There is local concern that this gravel berm increases flood levels within the River Cree. Therefore, removal of the berm has been considered.

2.11.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-10. Scores for this option were relatively low resulting from the expected detriment to the local environment, and the small additional flow area provided through removal of this feature. The overall score for this option placed it low in the ranked long list (<=40%).

Table 2-10 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
33%	43%	28%	59%	**40%**

2.11.3 Feedback from Stakeholders

The CVCC representatives at the VM1 meeting commented on the strong feeling from the community that this berm should be removed. It is felt that there has been a substantial change in the height of the berm over time and this has contributed to flood risk. There are also two further islands that are also thought, within the local community, to result in flow backing up throughout the town. This may be exacerbated by the presence of vegetation and trees, the growth of which is facilitated by the presence of the gravel berm. CVCC also noted a preference for this option, in their letter to DGC ahead of the VM1 meeting, as they felt it pushes water over towards the western bank adding pressure to the wall at Riverside Road.

Kaya Consulting concluded that, considering the hydraulics of the system, the impact of removing the gravel berm on flood risk would be minimal. Reference is made to the initial modelling exercise that found low impact following removal.

DGC felt that any removal of trees on the berm could result in a negative visual impact for those with properties on the east side of the river. They also noted that historical mapping has shown the berm to always be there.

SEPA noted that a CAR license would be required to remove this material from the river. Authorisation for this would be possible, however monitoring of the build-up would be needed in the first instance and a benefit to flood risk would need to be demonstrated.

Given that modelling shows that removal of the gravel berm and associated vegetation has very little impact upon flood risk, DGC would not consider its removal is merited with respect to duties imposed by Section 18 of the Flood Risk Management (Scotland) Act 2009.

2.11.4 Decision

This option will not proceed to the short-list. This was due to the very low impact that berm removal on predicted flood levels within the town, as demonstrated by Kaya Consulting.

An agreement was reached between CVCC and DGC to look at other maintenance issues surrounding the gravel berm and vegetation growth thereupon. This was agreed to be carried out separately to the Flood Protection Scheme.

2.12 Option 11: Removal of In-Line Weir (Town Centre)

This option sought to remove an obstruction to flow, as shown in Figure 2-11.

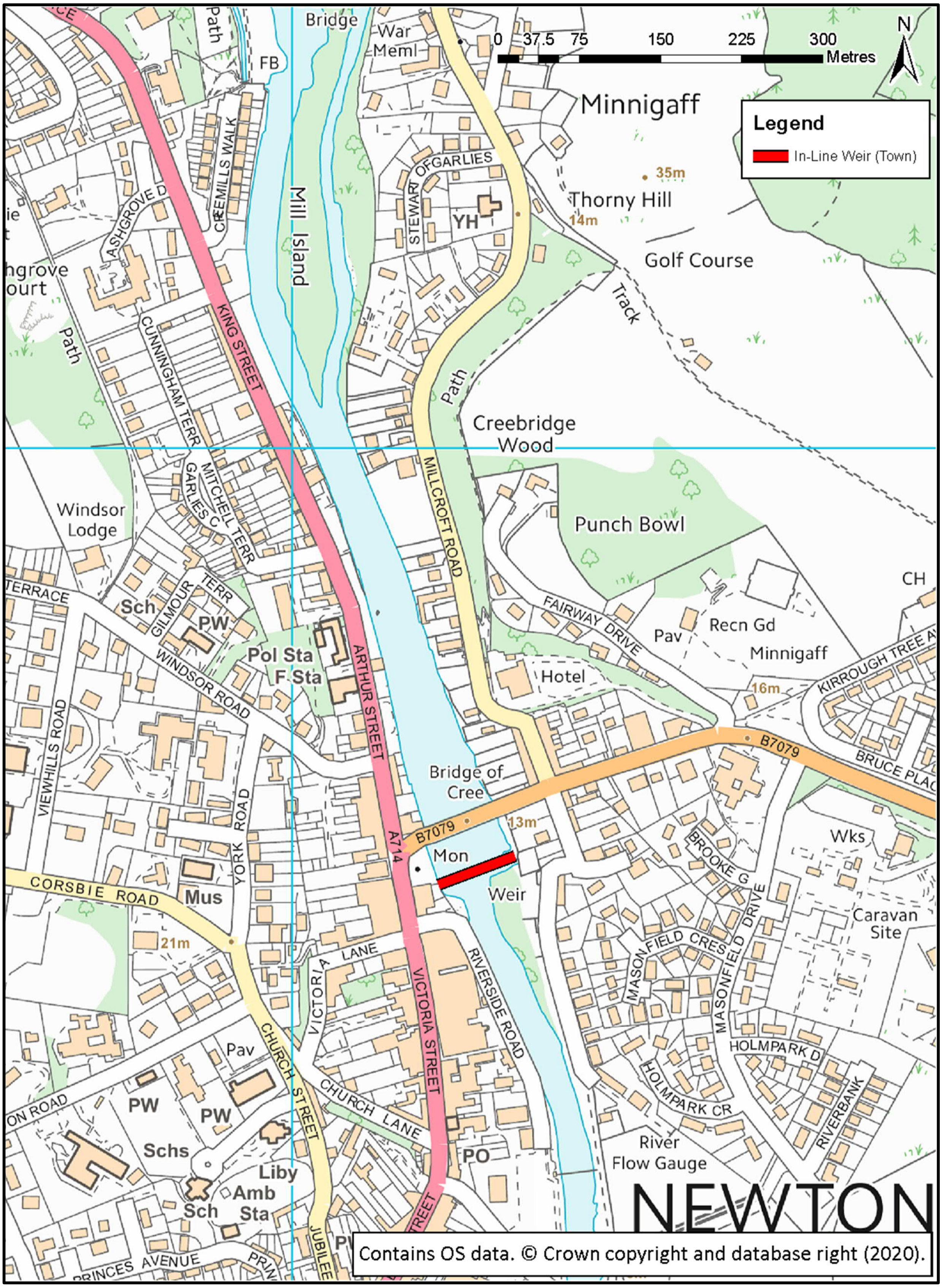

Figure 2-11 - In-Line Weir Location

2.12.1 Background

An in-line weir exists within the town centre, situated between the Cree Bridge and the gravel berm. This weir raises water levels upstream, and lowers flow velocities under normal conditions contributing to the high deposition rate locally.

2.12.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-11. Scores for this option were relatively low resulting from the expected detriment to the local environment and the additional consideration of the Cree Bridge upstream, which would be subject to additional flow velocities in the event of weir removal. The overall score for this option placed it low (<40%) in the ranked long list.

Table 2-11 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
16%	41%	23%	59%	**32%**

2.12.3 Feedback from Stakeholders

Kaya Consulting carried out some hydraulic modelling on this option ahead of the VM1 meeting, and stated that this option reduced flood levels by approximately 400mm locally.

There was local concern that the weir was causing a build-up of gravel and DGC commented that this build-up is being monitored.

2.12.4 Decision

This option did not proceed to the short-list due to the risk of increased scour to the Cree Bridge.

2.13 Option 12: Removal of In-Line Weir (Upstream of Town)

This option sought to remove a barrier to flow, as shown in Figure 2-11.

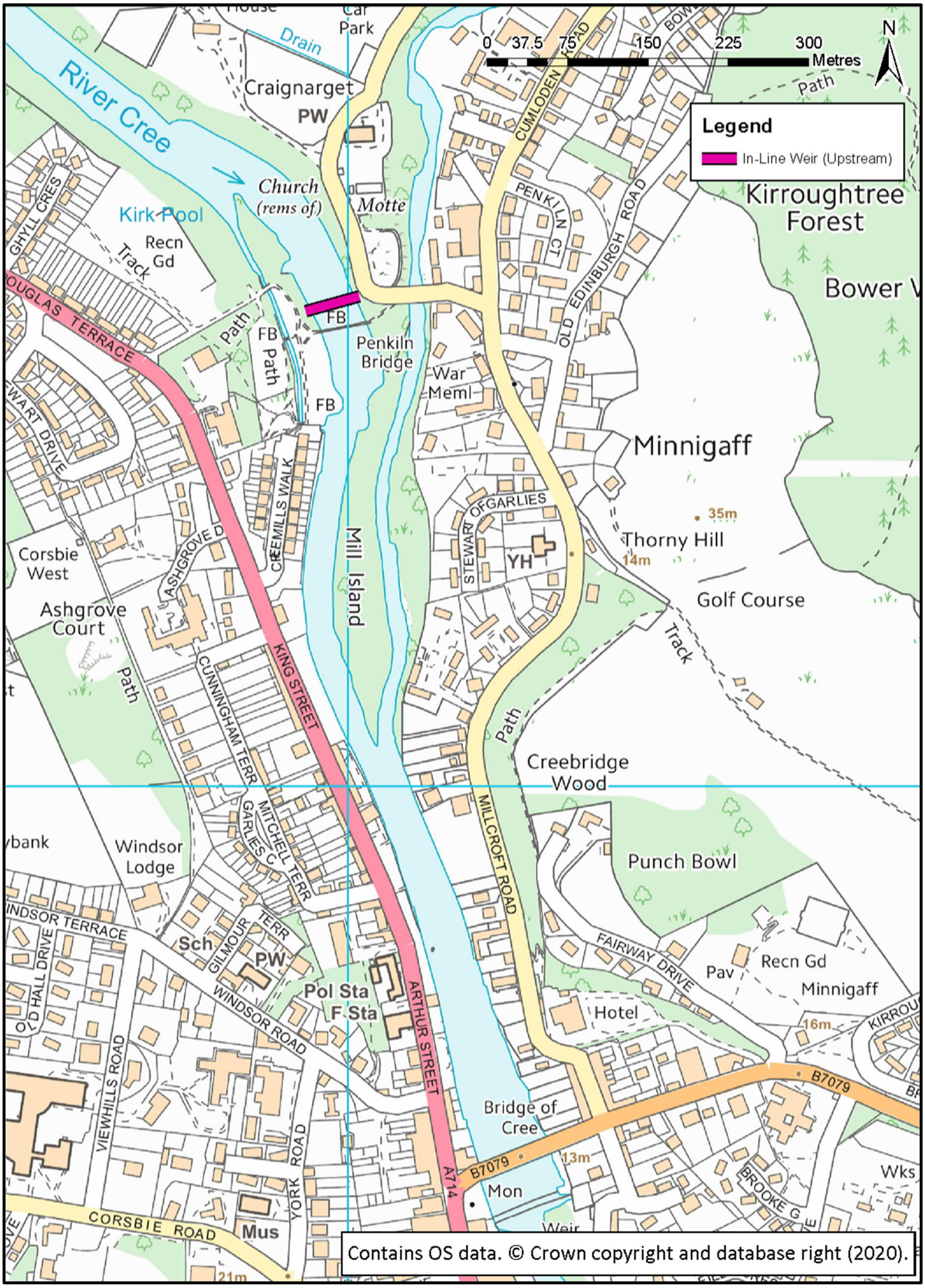

Figure 2-12 - Upstream Weir Location

2.13.1 Background

A weir (or part thereof) is suspected to exist just upstream of the town, as part of the former mill operations nearby. Similar to Option 11, it may be that removal of this weir could reduce water levels locally.

2.13.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-12. This option has failed based on the very low impact this option would have on flood levels within the town.

Table 2-12 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
FAIL	FAIL	23%	59%	**FAIL**

2.13.3 Feedback from Stakeholders

Galloway Fisheries noted that there are a series of weirs at this location and that the lowest one has already been completely removed.

Further discussion at the VM1 meeting found that there are still two small weirs at this location, although the conclusion was reached that as they hold water back there would be no benefit to their removal.

2.13.4 Decision

This option was not progressed to the short-list due to the risk of increased flood risk.

2.14 Option 13: Reconnect Penkiln Burn and River Cree Upstream

This option sought to better utilise in-bank storage, as shown in Figure 2-13.

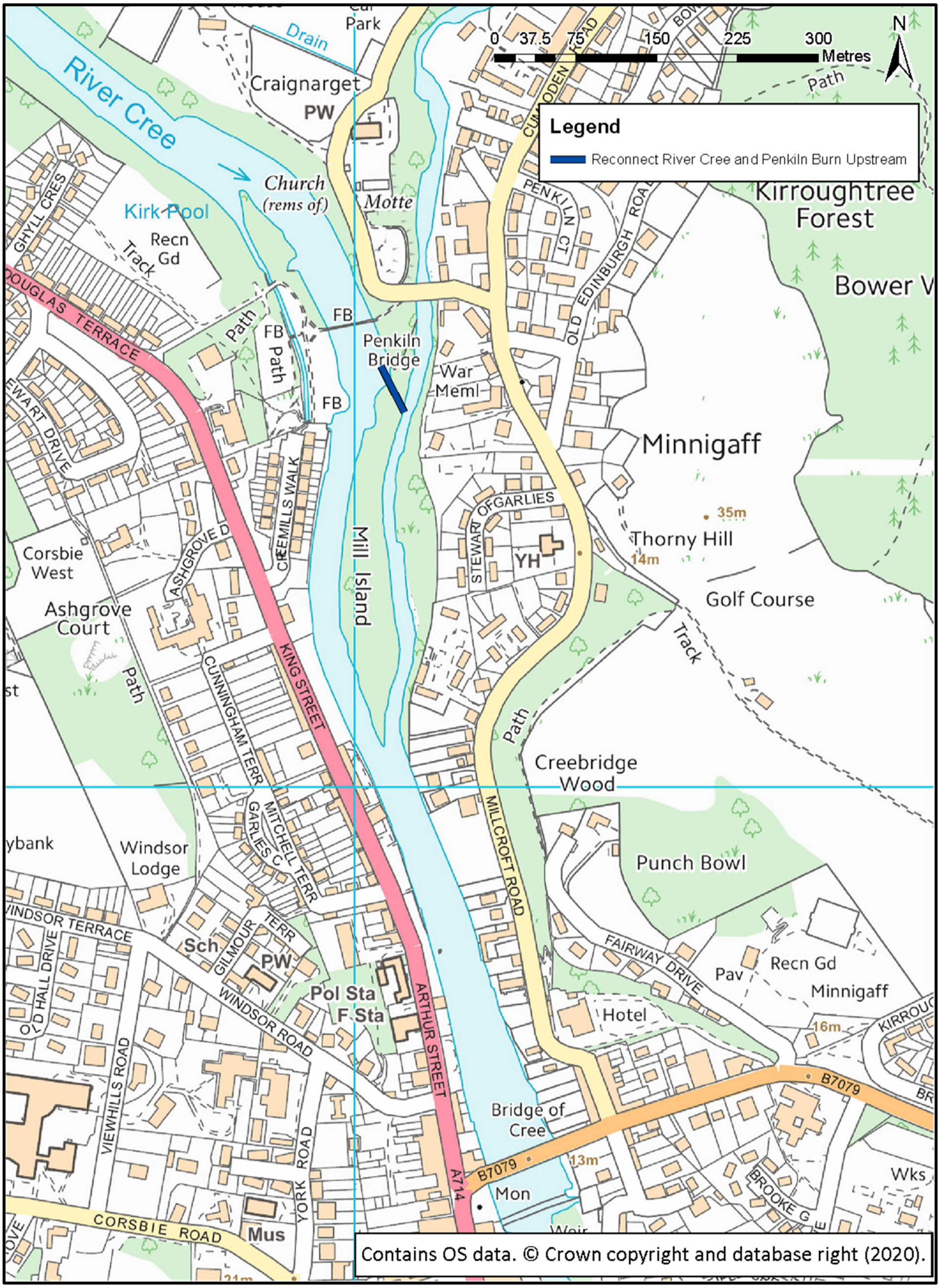

Figure 2-13 - Possible Reconnection of Watercourses

2.14.1 Background

Historical mapping showed the River Cree to be linked to the Penkiln Burn at a location north of the current confluence.

2.14.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-13. This option scored very low on technical and economic aspects due to the likelihood that this option will not reduce flood levels within the town, as flow will still be directed towards the current flood risk areas - albeit via a different route. There were also significant environmental concerns regarding excavation to accommodate this option. The option failed for these reasons.

Table 2-13 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
FAIL	21%	18%	41%	**FAIL**

2.14.3 Feedback from Stakeholders

The general consensus at the VM1 meeting was that this option was not feasible.

2.14.4 Decision

This option did not proceed to the short-list. This was because any reconnection would simply route water towards the town via a different channel, thus having no effect on flood alleviation. Note that at present, during high flows water does spill from the River Cree to the Penkiln Burn via the line shown on Figure 2-13 above.

2.15 Option 14: Remove Mill Island

This option sought to improve in-bank storage, as shown in Figure 2-14.

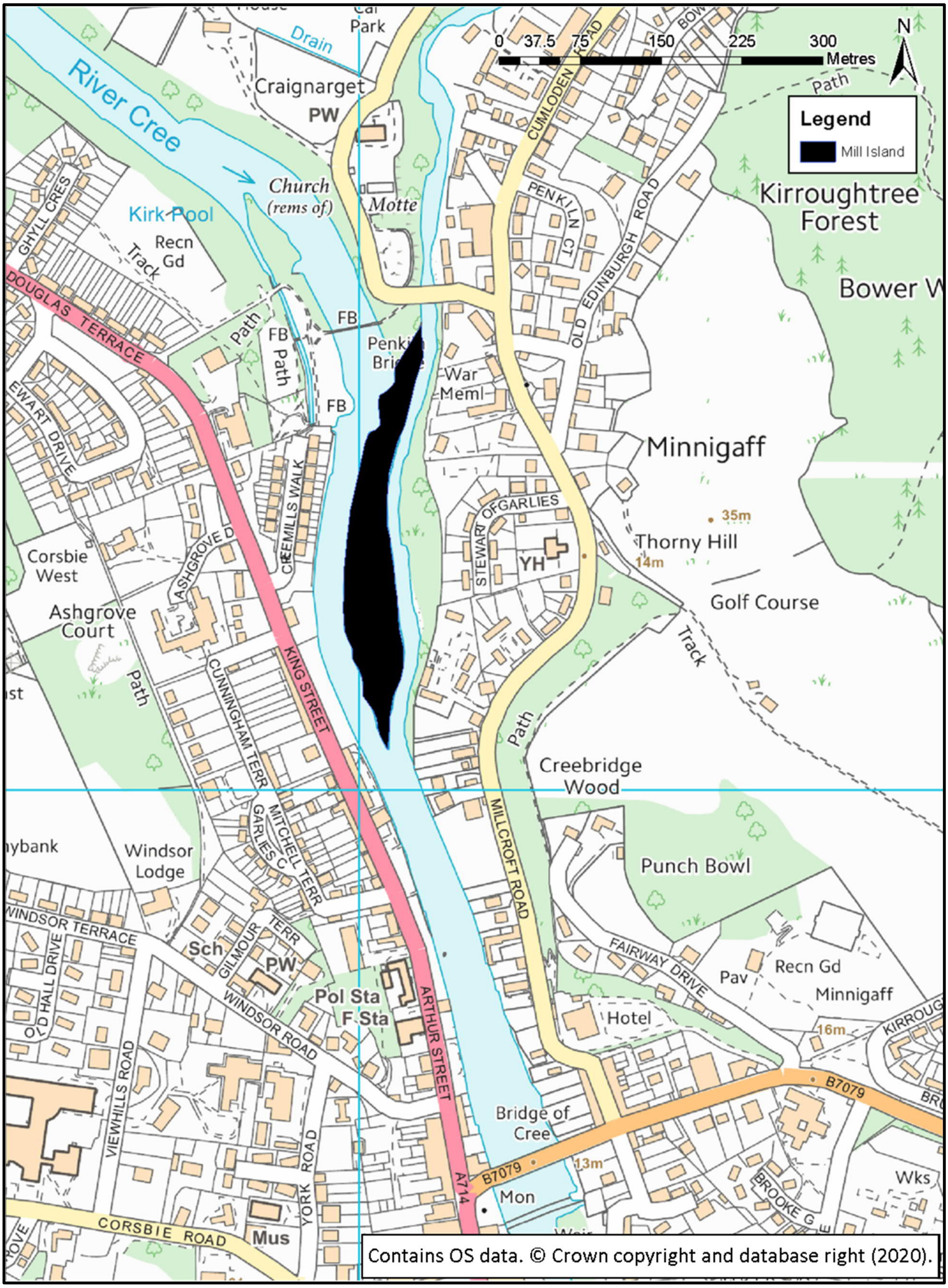

Figure 2-14 - Mill Island

2.15.1 Background

Mill Island exists between the River Cree and Penkiln Burn. Removal of this island would create a wider channel at the confluence point between the two watercourses. This may result in increased conveyance locally, resulting in reduced likelihood of out-of-bank flow locally.

2.15.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-14. Similar to nearby Option 13, the environmental impact of this option was considered to be negative. Furthermore, the impact on flood levels throughout the town was thought to be low as the funnelling effect created through removal of the island would cause out-of-bank flow at a location further downstream. There were also significant environmental concerns regarding excavation to accommodate this option. This option failed for these reasons.

Table 2-14 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
FAIL	46%	25%	59%	**FAIL**

2.15.3 Feedback from Stakeholders

The general consensus at the VM1 meeting was that this option was not feasible.

2.15.4 Decision

This option did not proceed to the short-list because removal of the island may have a funnelling effect downstream, and was not likely to yield any improvement to flood levels within the town itself.

2.16 Option 15: Remove Sediment Around Key Structures

This option sought to increase in-bank storage, as shown in Figure 2-15.

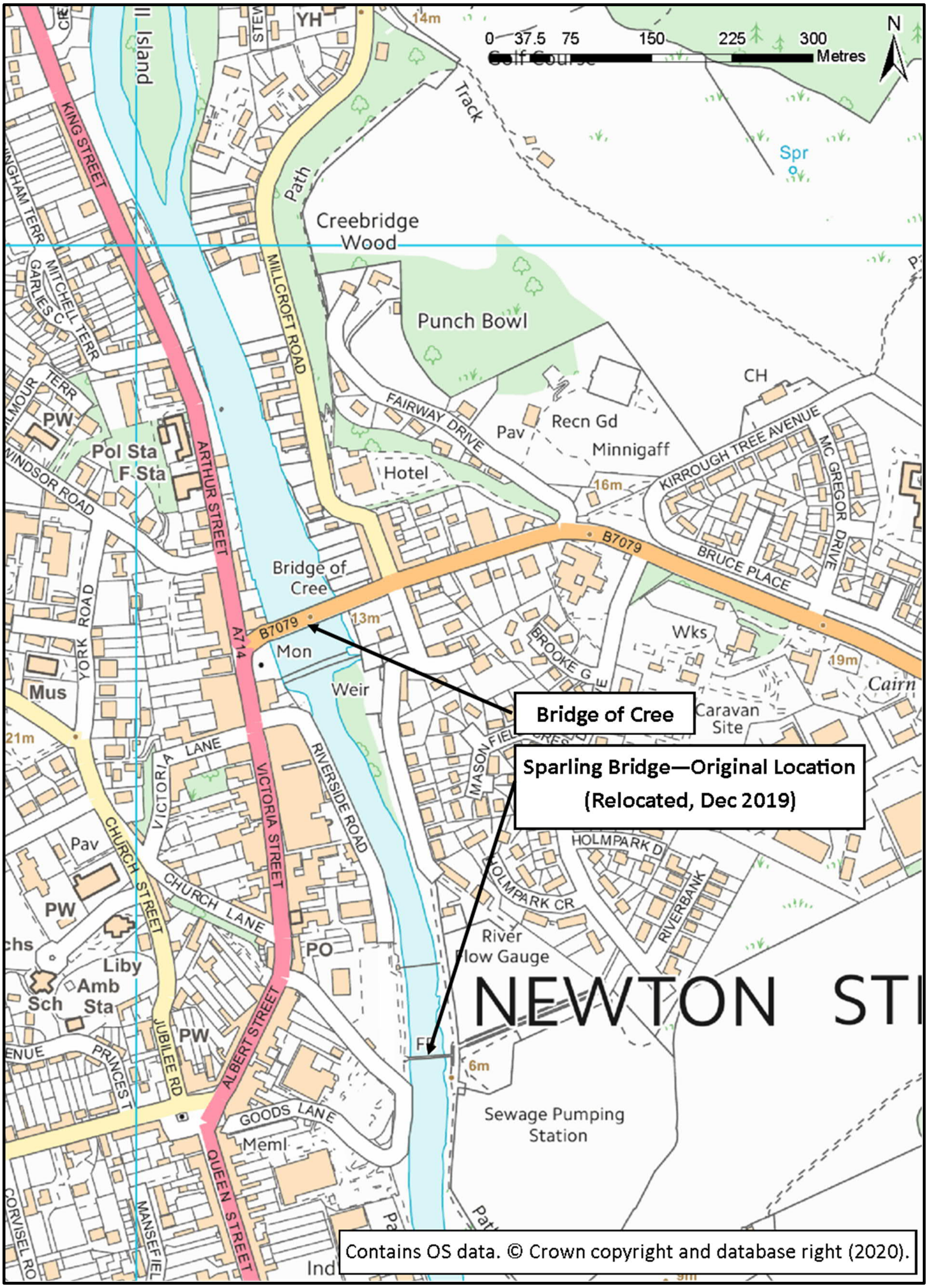

Figure 2-15 - In-Channel Structures

2.16.1 Background

Morphological activity in the River Cree is locally high, as outlined on SEPAs Sediment Management mapping. Concerns were raised by the community that excessive build-up could increase water levels. This option looked at the removal of sediment build-up around key structures where deposition may have taken place. For clarity, this option focused only on the removal of excessive sediment deposits at structures, distinct from dredging.

2.16.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-15. Similar to Option 13, the environmental impact of this option was considered to be negative. Furthermore, the impact on flood levels throughout the town was thought to be low as the funnelling effect created through removal of the island would cause out-of-bank flow at a location further downstream. There were also significant environmental concerns regarding excavation to accommodate this option. The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-15 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
35%	56%	33%	38%	**42%**

2.16.3 Feedback from Stakeholders

CVCC noted, in their letter to DGC ahead of the VM1 meeting, that they felt it would be valuable to remove the stone deposits within this area.

There were local concerns that sediment build-up was resulting in greater force on the Cree Bridge from flow during times of flood. DGC commented that their assessment found the bridge unlikely to fail via this mechanism. The consensus was that this option would have minimal benefit.

2.16.4 Decision

This option did not proceed to the short-list. This was because small deposits in this area are unlikely to have a significant effect on reduction of flood risk if removed, and furthermore that their presence did not pose any additional risk to the structures themselves.

2.17 Option 16: Divert Penkiln Burn

This option sought to reduce the volume of water passing through the town, see Figure 2-16.

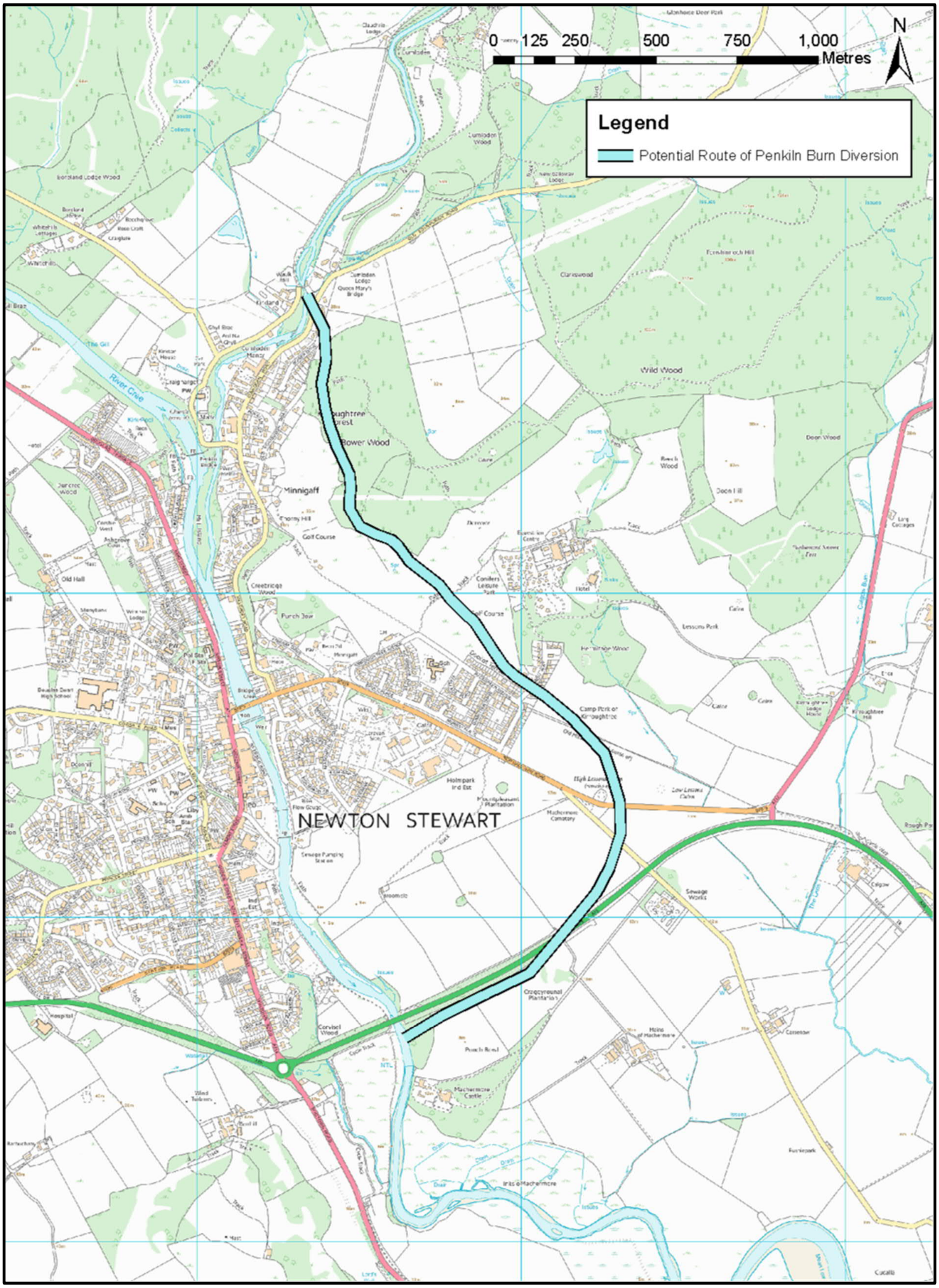

Figure 2-16 - Potential Diversion Route, Penkiln Burn

2.17.1 Background

The topography of the land to the north-east of the town can accommodate a diversion channel to re-route some flow from the Penkiln Burn to the River Cree downstream of the A75T crossing.

2.17.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-16. This option would have been costly and disruptive both to the local environment and residents, hence the low scores on economic, environmental and social. The overall score for this option placed it low in the ranked long list (<40%).

Table 2-16 -Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
40%	25%	20%	19%	**29%**

2.17.3 Feedback from Stakeholders

Consensus reached at the VM1 meeting was that this option could cause environmental and landowner based issues. Furthermore, the option would have only diverted some flow from the Penkiln Burn, which account for approximately 15% of the flow towards the town, thus the expected impact would be minimal.

2.17.4 Decision

This option did not proceed to the short-list. This was due to the significant scale of the works required; the high cost and disruption associated with the option; the low likelihood of being constructed within a reasonable timeframe; and low impact on flows towards the town.

2.18 Option 17: Dredging of River

This option sought to improve in-bank storage and conveyance, as shown in Figure 2-17.

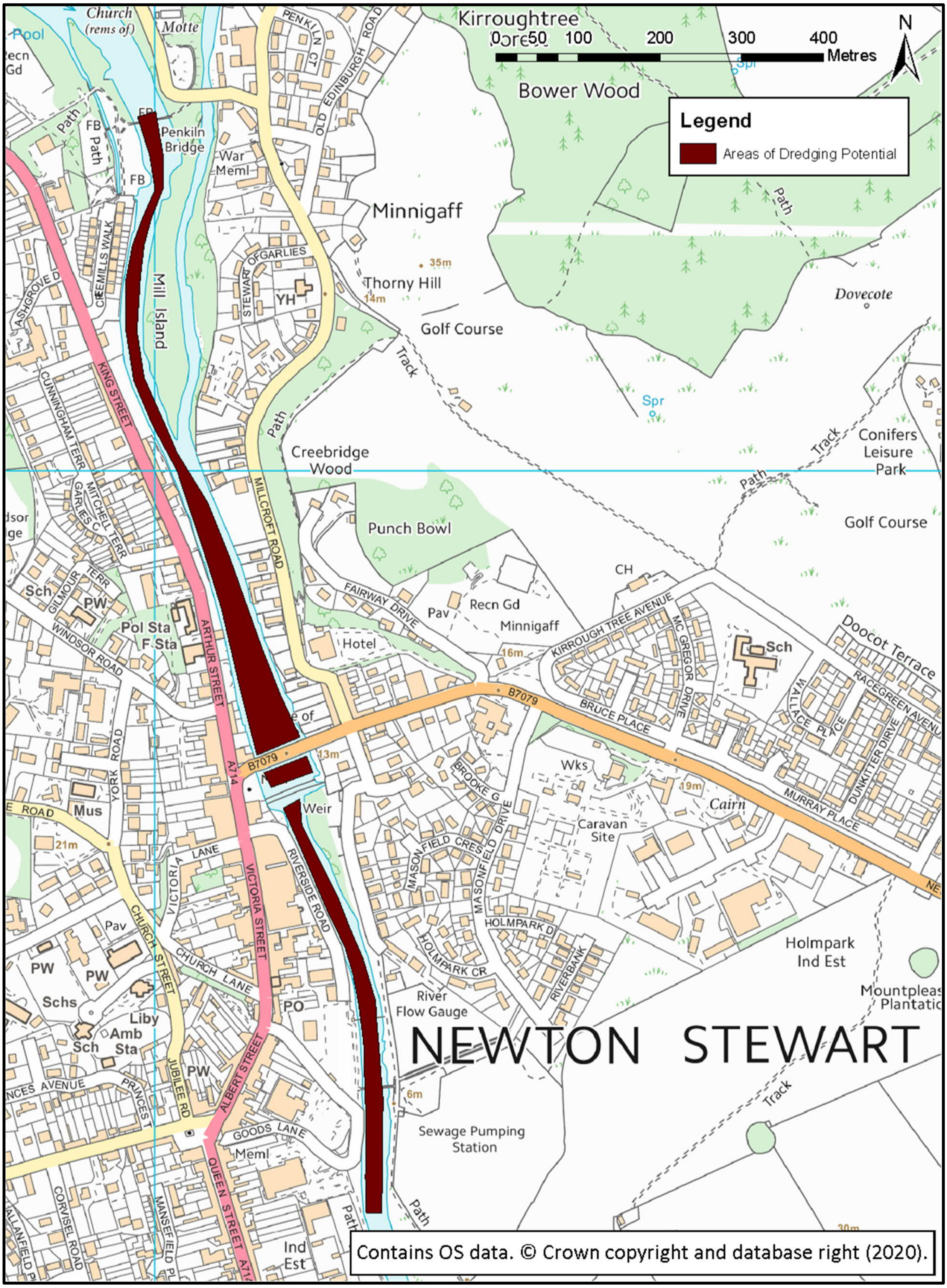

Figure 2-17 - Areas of Dredging Potential

2.18.1 Background

Dredging is the process whereby river bed levels are excavated to provide greater conveyance area for the flow; hence increasing the capacity of the river. The dredging process comes at a cost of being a temporary measure, and produces the requirement for the watercourse to be dredged at regular intervals in the future to continue to provide the same standard of flood protection.

2.18.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-17. This option failed the assessment as SEPA guidelines require all other options to be eliminated ahead of new dredging areas. A high number of other options were available, hence the likelihood of gaining authorisation to dredge was low.

Table 2-17 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
36%	56%	FAIL	69%	**FAIL**

2.18.3 Feedback from Stakeholders

SEPA noted that a CAR license would be required. Authorisation for this would have necessitated the provision of a sediment management plan to ensure that dredging continues at regular intervals in the future. Future dredging work increases the whole life cost of this option to the point of being economically unsustainable.

Further discussion at the VM1 meeting concluded dredging operations could also have negative implications on the stability of structures.

2.18.4 Decision

This option did not proceed to the short-list. This was because the dredging operation would be needed at regular intervals in the future. Additionally, the concerns regarding structures along the watercourse, particularly the Cree Bridge, were high.

2.19 Option 18: Disconnect Former Mill Lade

This option sought to alter flood pathways, as shown in Figure 2-18.

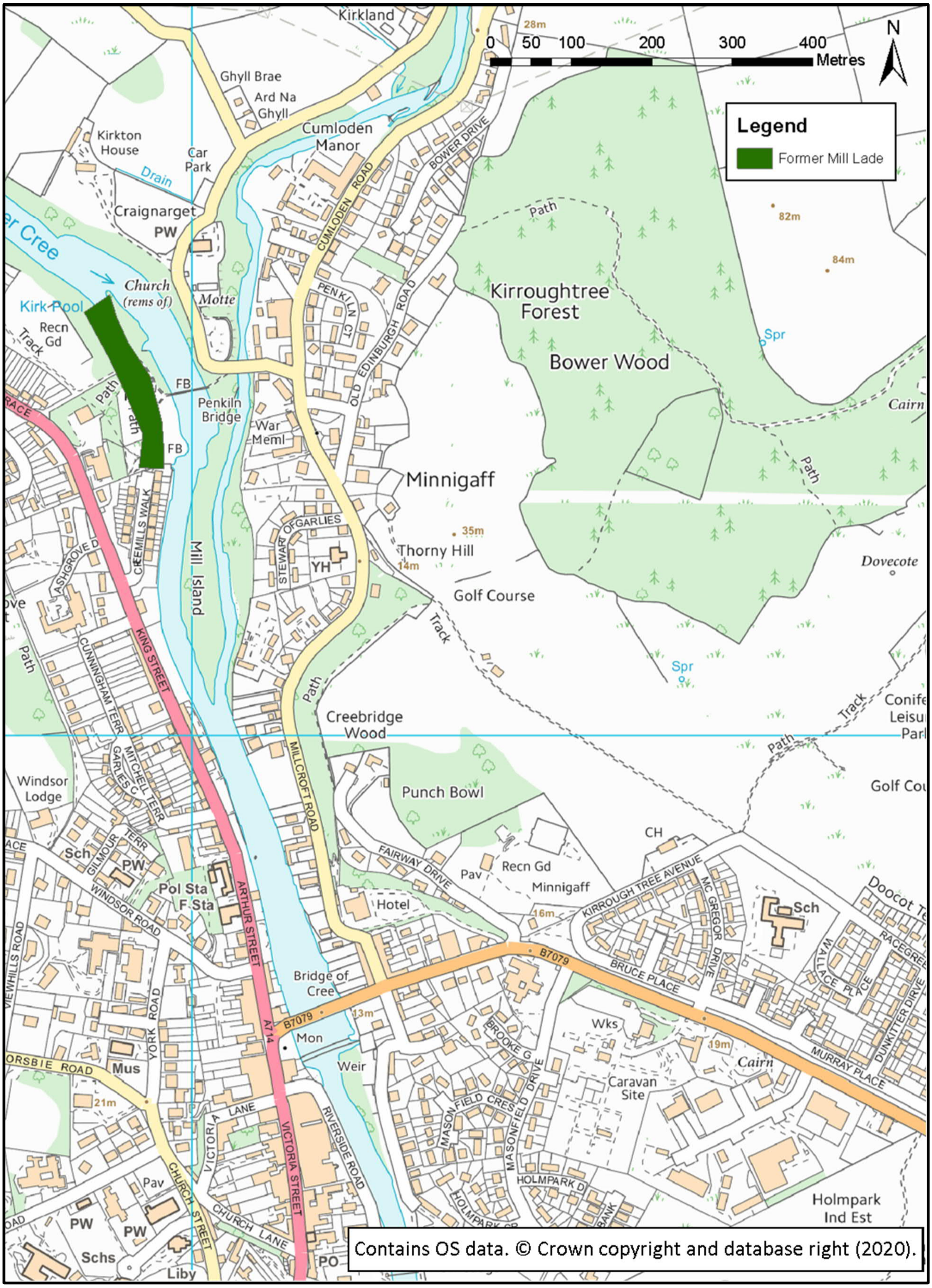

Figure 2-18 - Former Mill Lade

2.19.1 Background

A former mill lade was identified on the River Cree at the northern edge of the town. Disconnection of this mill lade may impact on flows locally.

2.19.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-18. This option failed the assessment as recent development within the area has already created a barrier between the mill lade and residential receptors, constructed to the 1:200 year return period standard in line with Scottish Planning Policy.

Table 2-18 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
FAIL	50%	48%	53%	**FAIL**

2.19.3 Feedback from Stakeholders

Feedback from CVCC was that a new development was constructed here recently that has alleviated flooding in the local area. This new development has already shown itself to be resilient to out-of-bank flow events although garden flooding has been reported.

2.19.4 Decision

This option did not proceed to the short-list because the local properties were found to be protected/resilient.

2.20 Option 19: Re-profile Land at Broomisle

This option sought to improve floodplain storage and attenuation, as shown in Figure 2-19.

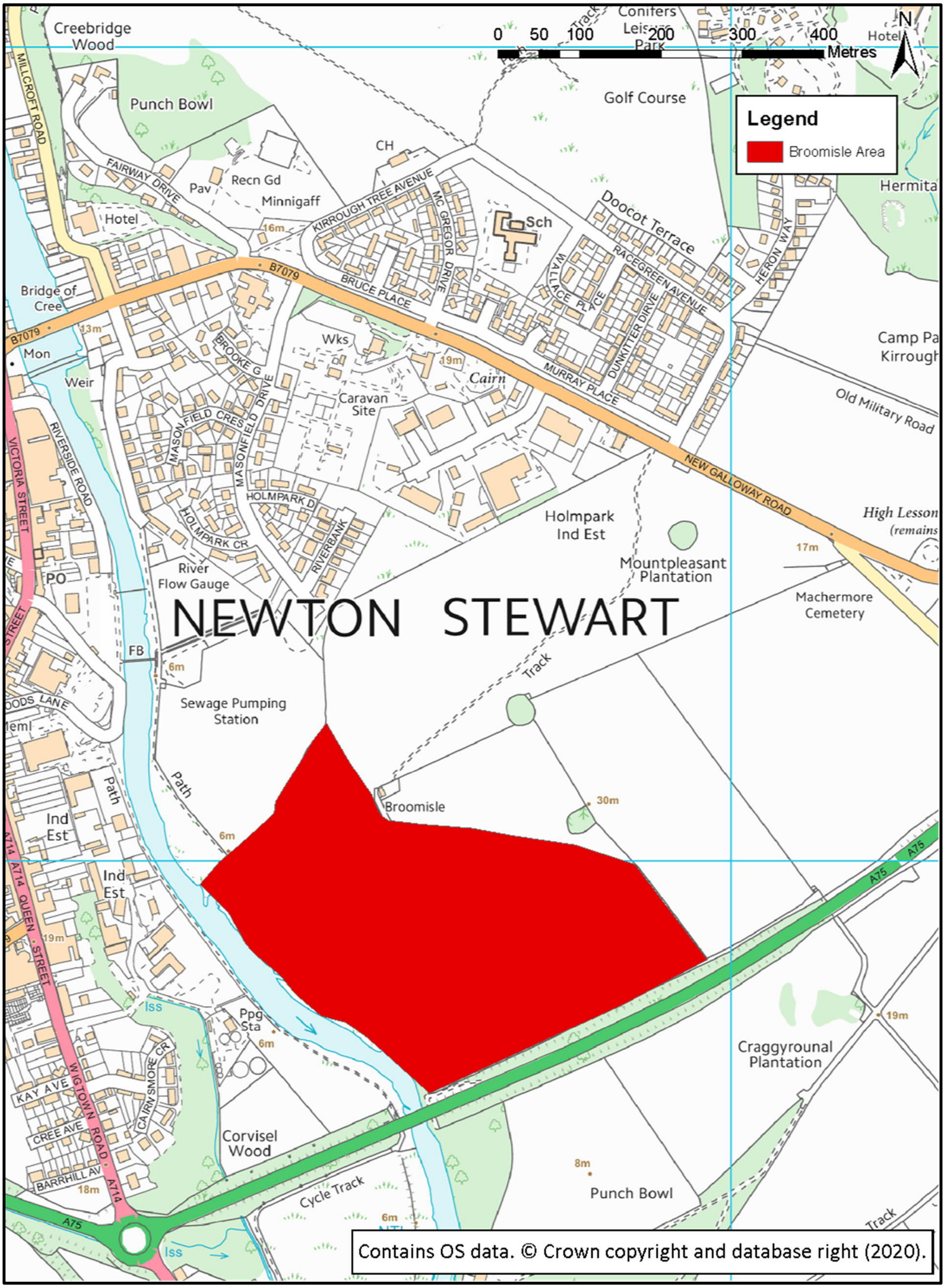

Figure 2-19 - Broomisle Area

2.20.1 Background

Downstream of the town, land at Broomisle was identified as a possible flood storage area. Re-profiling of this land to create storage may impact water levels locally. This option could be combined with amenity benefit, such as the creation of a new wetland/parkland area.

2.20.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-19. Considering the high volumes of water at extreme events, it was unlikely that this option could exist alone, and as such the economic score is low. The overall score for this option placed it high in the ranked long list (>60%), resulting from ease of construction.

Table 2-19 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
89%	46%	51%	56%	**63%**

2.20.3 Feedback from Stakeholders

CVCC noted, in their letter to DGC ahead of the VM1 meeting, that increasing access to additional areas of floodplain from the river is an important issue (suggesting support for this option). No further feedback was gained at the VM1 meeting itself, but a consensus was reached that the option should be examined further.

2.20.4 Decision

This option was progressed to the short-list. The reason for this was that additional survey data was needed to fully understand the potential benefits here. This data was received and Kaya Consulting has carried out further modelling of this option – with results presented in Section 3.6.

2.21 Option 20: Reinstate Flood Storage Area at Water of Minnoch

This option sought to attenuate flow in the upper catchment, as shown in Figure 2-20.

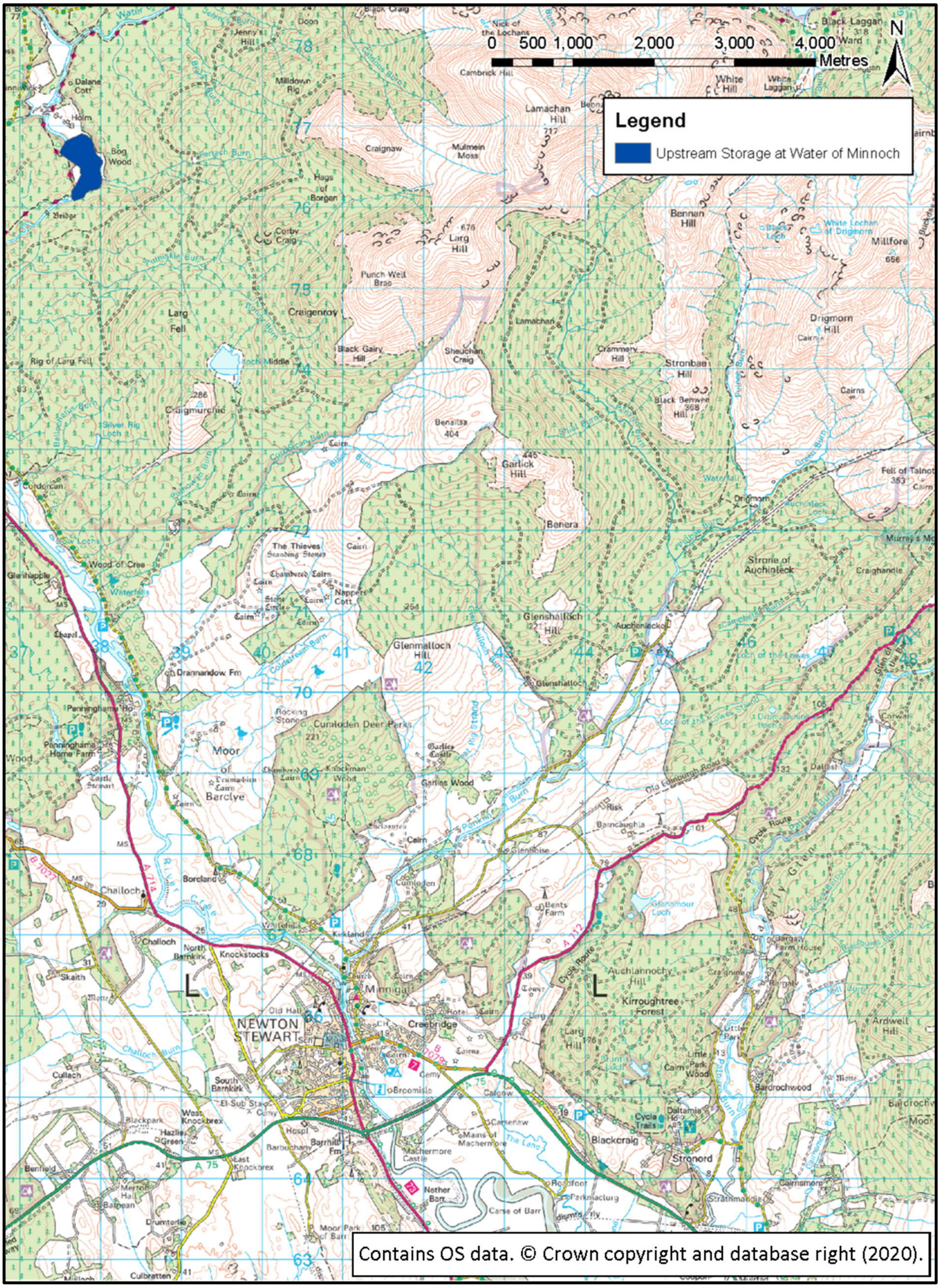

Figure 2-20 - Upstream Storage at Water of Minnoch

2.21.1 Background

This option considered bringing a former in-line flood storage area, on the Water of Minnoch, back into service with the intention to provide upstream storage similar to options 1, 2 and 3.

2.21.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-20. Constructability scores for this option were low, resulting from poor access to the area. Economically, the option scored low due to the relatively small available storage volume. The overall score for this option placed it low in the ranked long list (<40%).

Table 2-20 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
27%	15%	40%	88%	**34%**

2.21.3 Feedback from Stakeholders

CVCC noted, in their letter to DGC ahead of the VM1 meeting, that they believe there may be substantial opportunities in the upper catchment for storage of water.

Kaya Consulting reported that assessment in this area may be difficult due to the lack of LiDAR data.

2.21.4 Decision

This option was taken forward to the short-list for additional investigation. Kaya Consulting undertook a high-level appraisal of the option using OS data, in place of LiDAR data. Results of this additional analysis have been provided in Section 3.7.

2.22 Option 21: Upstream Storage at The Ghyll

This option sought to attenuate flow in the upper catchment, as shown in Figure 2-21.

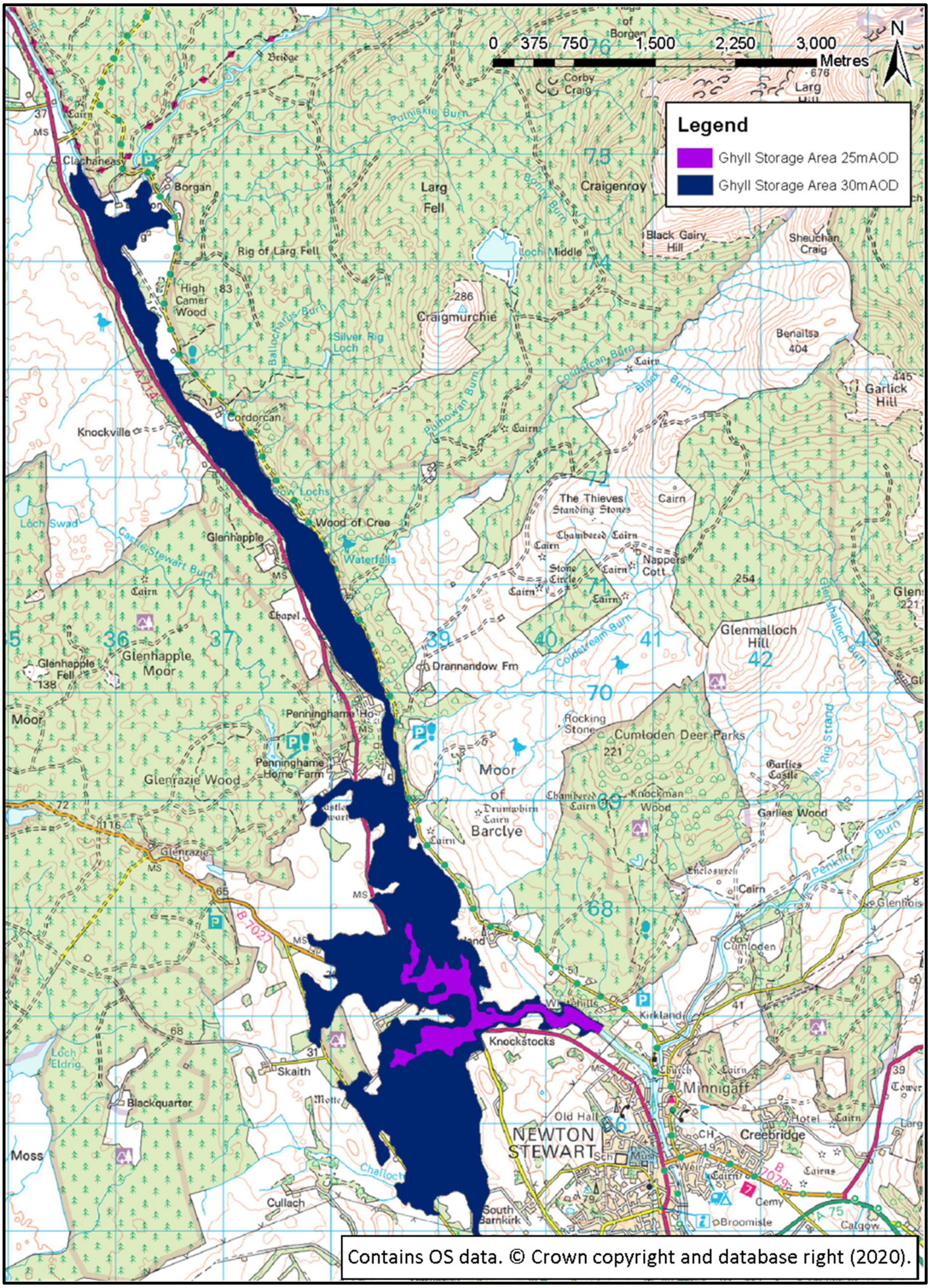

Figure 2-21 - The Ghyll Storage Area

2.22.1 Background

A deep valley in an area known as The Ghyll, just upstream of the town, has the potential to store a large volume of water. This would be an on-line storage area.

2.22.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-21. Technically, this option received a lower score due to the complexity of working in the valley. Economically, a high volume of water could be stored here (hence, high standard of protection) but the scheme cost was high. The overall score for this option placed it approximately within the middle of the ranked long list.

Table 2-21 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
39%	40%	49%	78%	**47%**

2.22.3 Feedback from Stakeholders

CVCC commented that this was a steep valley and that they believe a large volume of storage could be held here.

Galloway Fisheries and SEPA re-iterated their concerns about on-line storage areas.

2.22.4 Decision

This option was taken forward to the short-list. Kaya Consulting carried out additional modelling, with results presented in Section 3.8.

2.23 Option 22: Upstream Storage in River Cree Tributaries

This option sought to attenuate flow in the upper catchment, as shown in Figure 2-22.

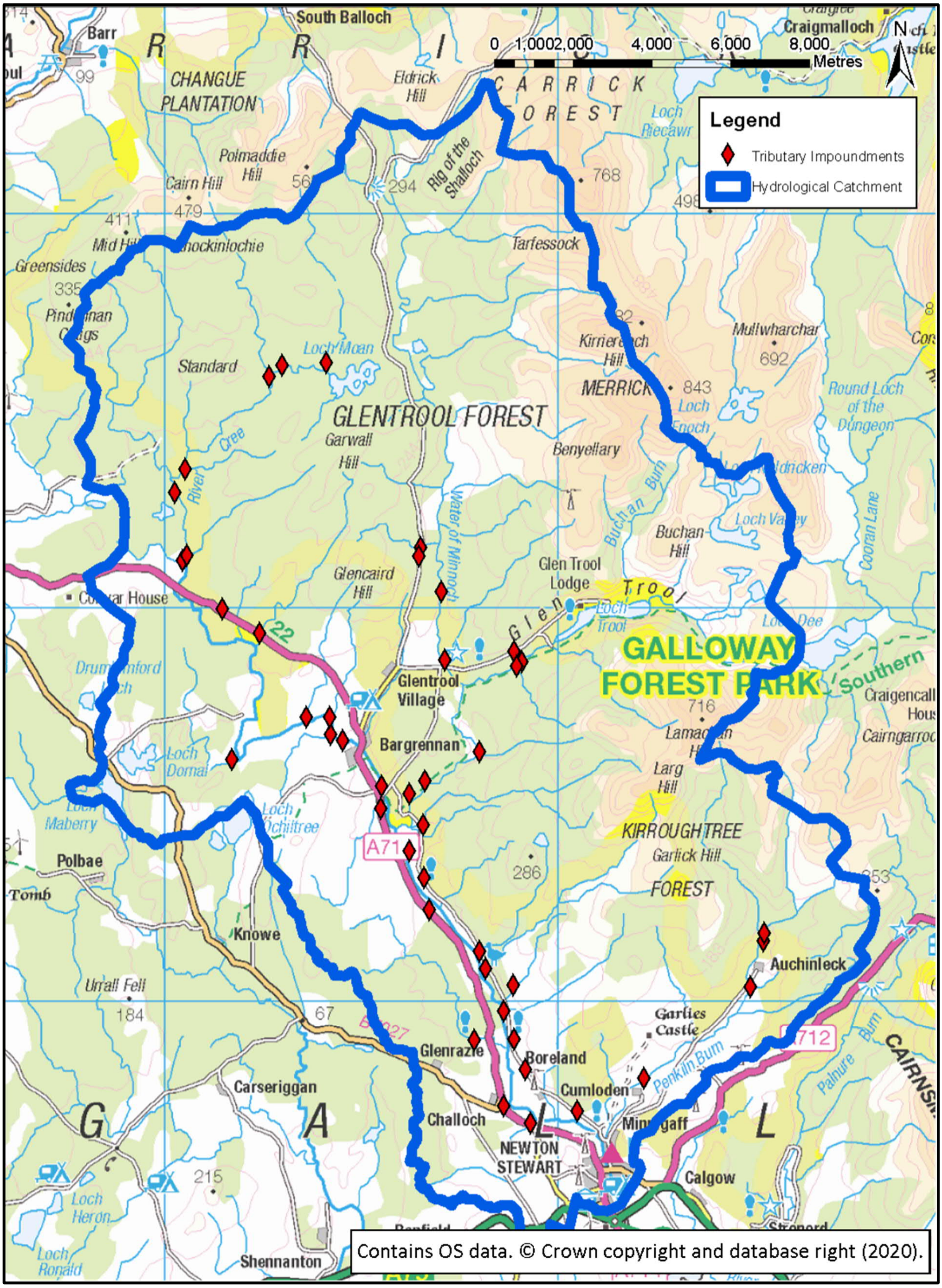

Figure 2-22 - Potential Tributary Impoundments

2.23.1 Background

The River Cree has many small tributaries, many of these are high in the catchment upstream of the town. The local community suggested that storage on these tributaries was investigated. A high-level assessment of this option has shown that small scale interventions on 44 tributaries would likely achieve some flood risk reduction. These interventions could comprise hard engineering impoundments or smaller scale Natural Flood Management (NFM) features.

2.23.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-22. Technically, this option was highly complex and would likely take a long time to implement due to the number of individual sites. Economically the options scores were low due to the cost of implementing 44 separate constructions. The overall score for this option placed it low in the ranked long list (<40%).

Table 2-22 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
35%	22%	40%	38%	**32%**

2.23.3 Feedback from Stakeholders

Forestry Commission Scotland stated they were happy to assist with any flood alleviation projects. However, they also stated concerns over additional responsibilities regarding any hard engineering impoundments, which they would not currently be able to undertake.

SEPA noted that each catchment would have its own characteristics and these would need to be considered in any further assessment of this option.

CVCC asked if NFM could be implemented in some locations rather than hard engineering structures.

A consensus was reached at the VM1 meeting: the 44 locations would be impractical, but that a small number of locations for Natural Flood Management (NFM) could be looked at which may be beneficial at low return period events.

2.23.4 Decision

This option was taken forward to the short-list. Only 7 locations were considered as it was concluded that 44 individual interventions would not meet the timescales required for the completion of the flood protection scheme. The results of this work have been presented in Section 3.9.

2.24 Option 23: Mitigation of Forest Management

This option sought to reduce runoff in the upstream forests, as shown in Figure 2-23.

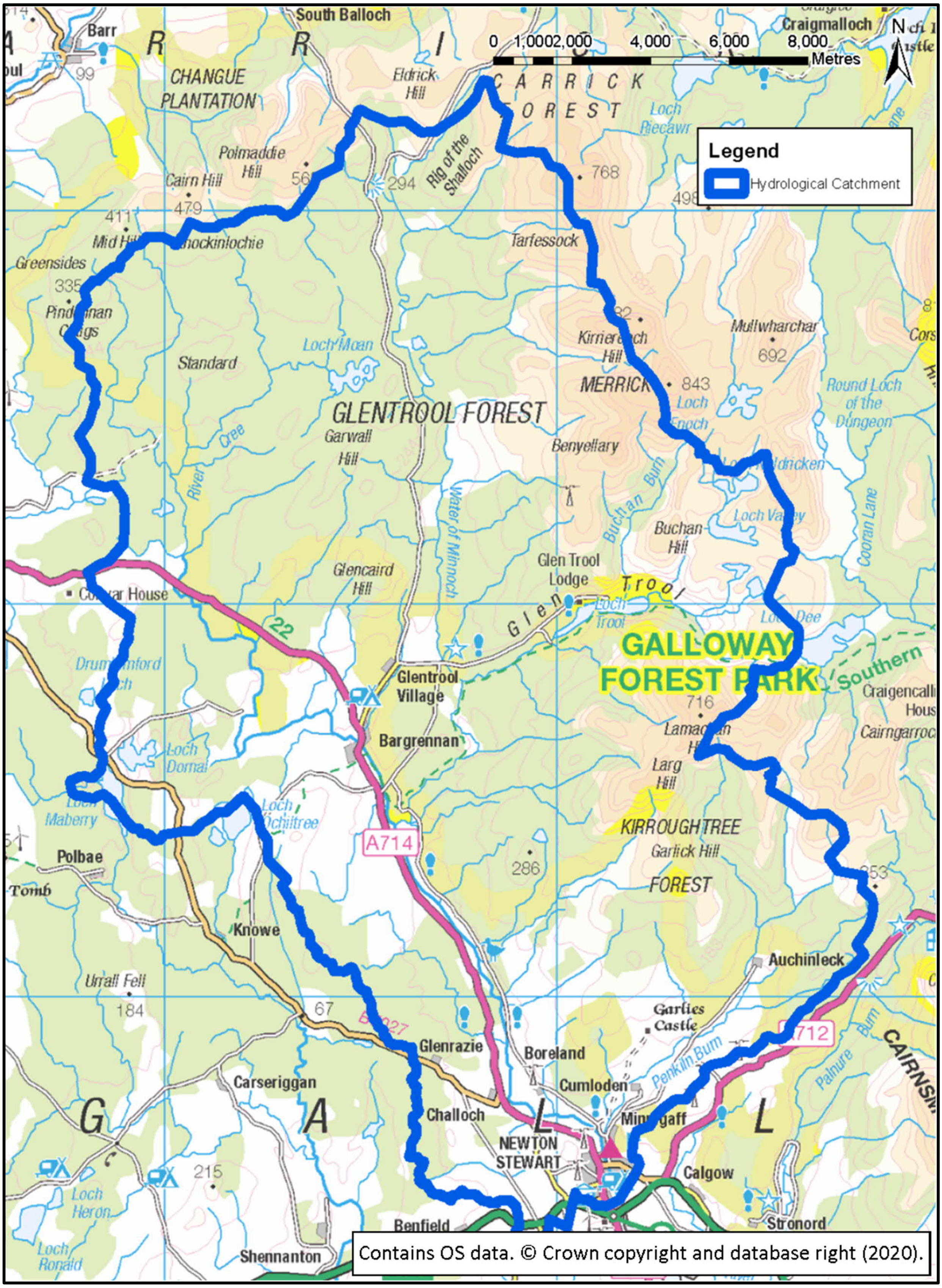

Figure 2-23 - Hydrological Catchment and Forestry

2.24.1 Background

Forest management practices, over both short and long term, have been perceived to increase rates of runoff in the upper catchment to the River Cree and its tributaries. It has been suggested by the local community that forms of natural flood management (NFM) in the upper catchment within the forest areas could help alleviate the situation.

2.24.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-23. Both technically and economically this option scored low due to the minimal reduction in flow that these techniques were likely to achieve. NFM measures scored highly within the environment and social categories as they are desirable for local people and visitors to the forest. The overall score for this option placed it low in the ranked long list (<40%).

Table 2-23 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
23%	25%	66%	78%	**39%**

2.24.3 Feedback from Stakeholders

Forestry Commission Scotland noted that the current forestry management practices are in line with NFM practises and that their work actively alleviates flooding. They believe that there is nothing further or additional that could be done, and would be happy to discuss their management plans to show that is currently being undertaken.

CVCC would prefer to see water held back within the upper catchment area, but SEPA noted that flood related benefits generally only exist in areas close to where an NFM intervention is located.

2.24.4 Decision

It was concluded, at the VM1 meeting, that this option was similar to option 22. As such, it was decided to merge this option with option 22.

2.25 Option 24: Re-profile Land Around Pumping Station

This option sought to improve floodplain storage, as shown in Figure 2-24.

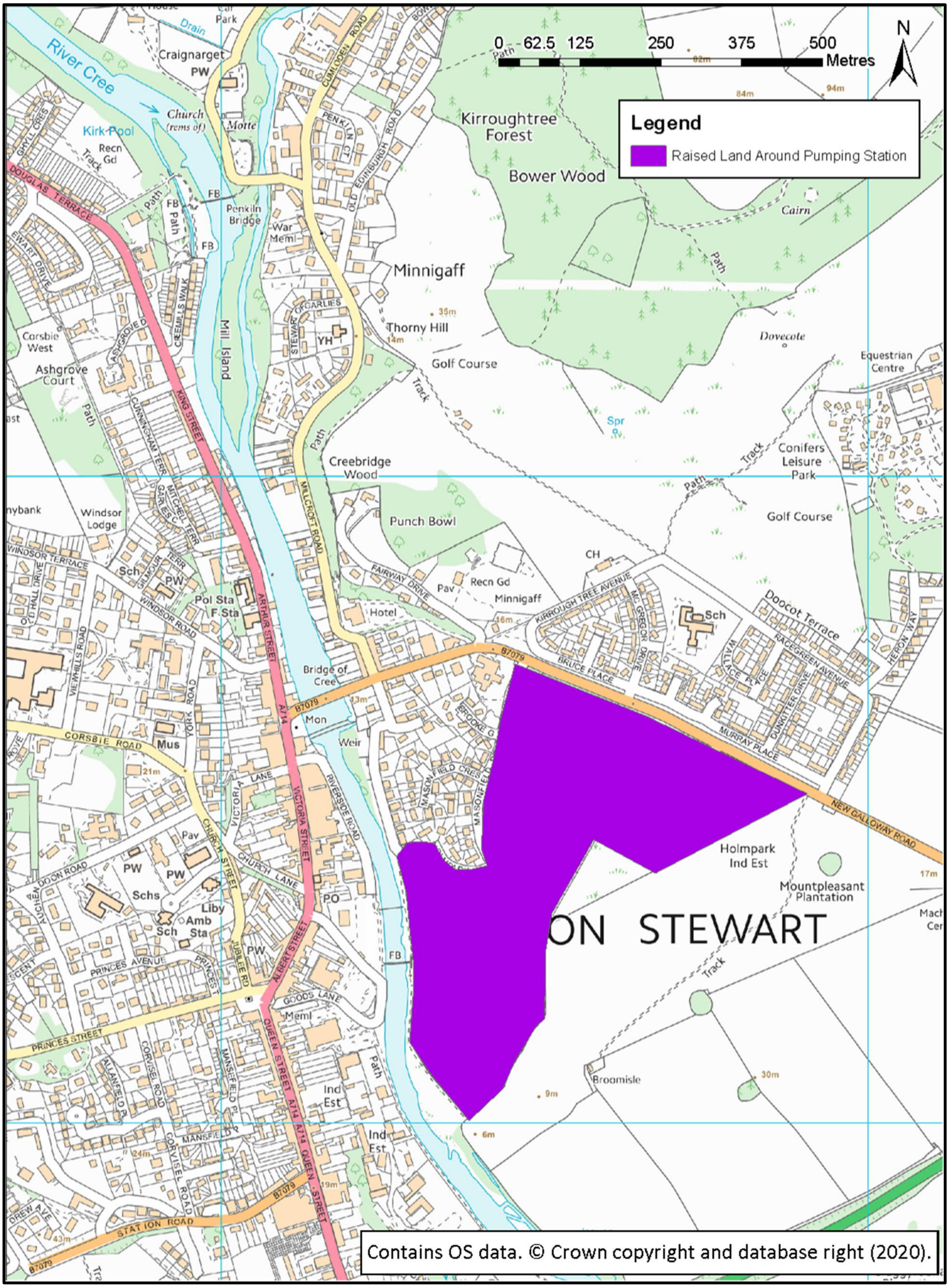

Figure 2-24 - Land Around Pumping Station

2.25.1 Background

Re-profiling of land in this area has been considered investigated. Local residents have reported that the pumping station on the east bank may be situated in the floodplain. Multiple reports cite flooding having been worsened since the construction of this pumping station. Further investigation has found that residential properties were also built near this pumping station, on land raised to the same level.

2.25.2 Multi-criteria Assessment

The outcomes from the multi-criteria assessment for this option have been provided in Table 2-24. Economically, this option scored poorly due to the likely requirement to move properties and facilities to other locations. Further impact resulting from these likely relocation requirements were that the score for social make the option a poor choice in terms of public perception. The overall score for this option placed it low in the ranked long list (<40%).

Table 2-24 - Multi-criteria Assessment Scores

Technical	Economic	Environmental	Social	Overall Score
44%	22%	53%	25%	**35%**

2.25.3 Feedback from Stakeholders

CVCC and elected members noted that the bund around the pumping station has resulted in noticeable increased flood levels since its construction.

DGC stated that it was not possible for the pumping station to be removed.

2.25.4 Decision

This option was taken forward to the short-list for additional investigation. Following receipt of additional survey data, Kaya Consulting carried out further modelling and results have been presented in Section 3.10.

2.26 VM1 Summary and Conclusions

The following options were taken forward for further assessment:

- Option 2 – Upstream storage at Linloskin Bridge
- Option 4 – Installation of Obstructions on River Cree
- Option 6 – Construction of Direct Defences
- Option 7 – Increase Flow Area Beneath A75T Bridge
- Option 9 – Increase A75T Flood Relief Culvert Size/Number
- Option 19 – Re-profile Land at Broomisle
- Option 20 – Reinstate Flood Storage Area at Water of Minnoch
- Option 21 – Upstream Storage Area at The Ghyll
- Option 22 – Upstream Storage in River Cree Tributaries
- Option 24 – Re-profile Land Around Pumping Station

The following upstream storage options were carried out ahead of the additional survey work to provide a high level assessment of the option feasibility:

- Storage at Linloskin Bridge (Option 2)
- Upstream obstruction in River Cree (Option 4)
- Upstream storage in Water of Minnoch (Option 20)
- Upstream storage at The Ghyll (Option 21)
- Upstream storage in *selected* tributaries (Option 22)

The following modelling investigations were carried out after receipt of additional survey data:

- Construction of Direct Defences (Option 6)
- Assessment of increasing flow area beneath the A75T bridge (Option 7)
- Increasing size of A75T flood relief culverts (Option 9)
- Reprofiling of land at Broomisle (Option 19)
- Reprofiling of land around pumping station (Option 24)

Following this modelling there were further civil engineering design and technical and environmental assessment of the options including a high-level costing exercise.

3 Short-List Options

This section presents the 10 options which were taken forward to the short-list following the initial assessment and discussion with stakeholders at, and ahead of, the VM1 meeting. This excludes the re-location of the Sparling Bridge, which had already been confirmed as a preferred option. Results of the assessment were presented to the stakeholders at the VM2 meeting. Discussion took place to reach consensus as to what the Preferred Options should be.

Short-list options were assessed in further detail under three general headings:

I. **Hydraulic Modelling:** Hydraulic and hydrologic modelling methods have been used to assess the standard of protection expected to be provided by each of the short-list options on a technical basis.

II. **Geo-Environmental:** Any geotechnical or environmental hazards at (or impacted by) any of the proposed short-list options have been identified and assessed.

III. **Cost-Benefit:** An estimate of the associated costs of building/maintaining the scheme along with potential benefits was made for each short-list option. A high-level BCR (benefit-cost ratio) was produced. A BCR of greater than 1.00 is required to support scheme funding. An *optimism bias* (addition % to account for uncertainties) of 60% has been applied. The optimism bias typically reduce as additional information becomes available and the scheme design progresses.

These three areas were used to assess suitability of the options present on the short-list. Any serious failings in the above three areas were highlighted and documented for each option, and were discussed at the VM2 meeting.

Details of each individual option and the associated discussion are presented in this section of the report, with a general overview of the process shown in Figure 3-1. As with the long-list options, feedback from stakeholders is provided under each option sub-section.

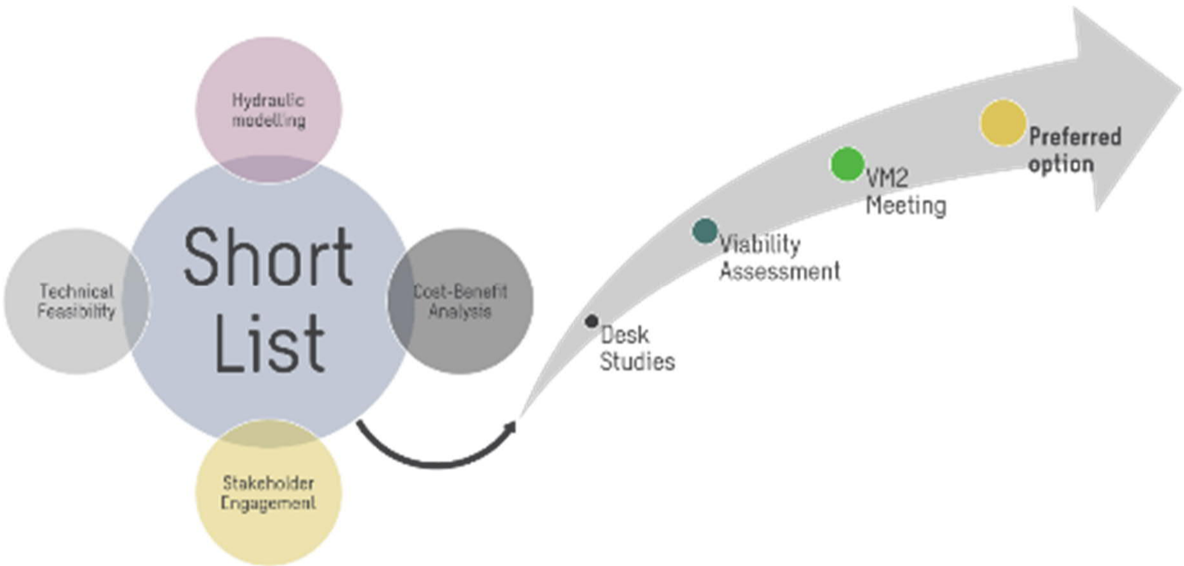

Figure 3-1 – Short-list to Preferred Option Process

3.1 Option 2: Upstream Storage at Linloskin Bridge

3.1.1 Background

Approximately 1.3 million m^3 of storage was identified behind a road crossing of a tributary of the River Cree at Linloskin Bridge. The location and predicted inundated area for this upstream storage option can be seen in Figure 3-2.

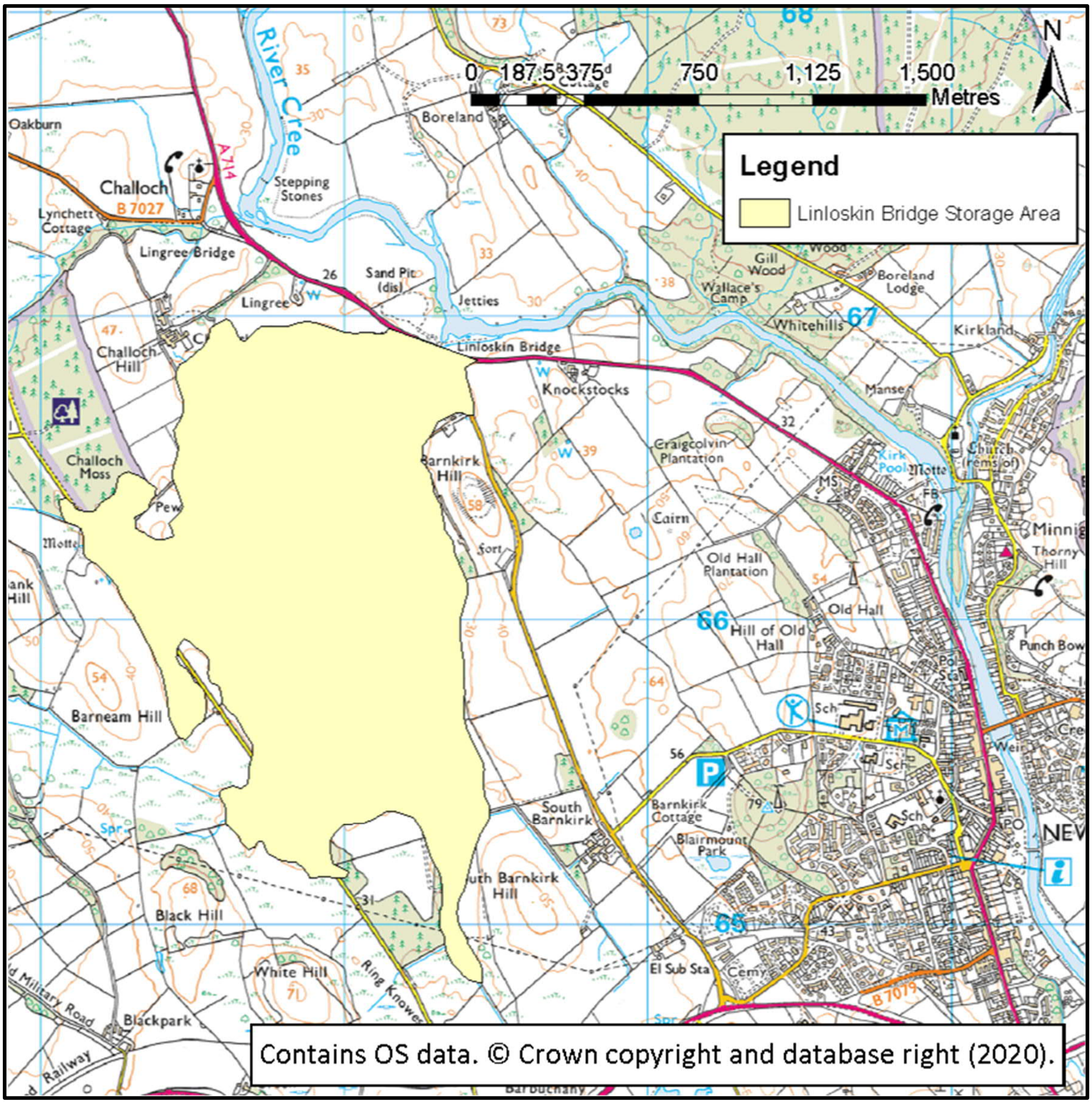

Figure 3-2 - Upstream Storage at Linloskin Bridge - Predicted Inundation Area Upstream

3.1.2 Specific Assessment Methodology Details

Two approaches were taken to this option: i) impoundment of the tributary only; and ii) routing of flow towards the area from the River Cree. The first of these options allowed for an assessment of what may happen if only flow from the Challoch Burn (whose confluence with the River Cree is immediately downstream of Linloskin Bridge) were to be impounded. The second of these options considered storing water from the River Cree, thus potentially delaying its arrival at the town.

In both cases, impoundment to a level of 26mAOD was assumed for optioneering purposes. Above this elevation any water within the storage area would overtop the A714 and return to the River Cree. Taking local topography into account, this would be equivalent to an impoundment height of approximately 2m.

For case (i) – looking at only the tributary – a small attenuation model was constructed, with peak flows in the Challoch Burn estimated using the FEH Rainfall-Runoff method. An outflow to restrict flows to a maximum of the equivalent 2-year return period event was included to account for the provision of a suitable base flow through the Challoch Burn. For case (ii) – looking at routing from the River Cree – the hydraulic model itself was extended upstream from the town to Linloskin Bridge using LiDAR. A spill to direct flow from the River Cree into the storage area was implemented, with the level of this spill set to route flows towards the storage area when they reached $195m^3/s$. This flow is equivalent to the point at which receptors in the town begin to inundate.

3.1.3 Hydraulic Modelling Findings

Modelling results looking at the impoundment of the Challoch Burn only (case (i)) returned results showing minimal impact. A predicted maximum reduction in peak flows of $4.9m^3/s$ was obtained for the 200-year return period event. This represents a reduction in peak flow at the town of 0.94% and thus shows there to be almost no impact.

Looking at the case where flow was routed from the River Cree towards the storage area, a predicted maximum reduction in peak flows $0.1m^3/s$ was found. This represents a reduction in peak flow at the town of 0.02% and thus shows there to be almost no impact.

3.1.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option have been presented in Table 3-1.

Table 3-1 - Upstream Storage at Linloskin Bridge - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries, sand and gravel pits	**Low**
Protected species designations for freshwater fish	**Medium**
Uncertainty regarding foundation material for potential structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.1.5 Cost-Benefit Findings

Considering the negligible decrease in flows predicted at the town for this option, a cost-benefit calculation was not carried out. This was because there were no reductions in the numbers of receptors, nor were there reductions in peak flood depths.

3.1.6 Feedback from Stakeholders

Comments were received from the CVCC on historical flooding, indicating that high flows in the River Cree would likely back-up along the Challoch Burn at Linloskin Bridge during extreme events. Further discussion agreed that there was limited flexibility on where an impoundment could be situated.

3.1.7 Decision

This option was removed from consideration as the option would not reduce flood risk within the town.

3.2 Option 4: Installation of Obstructions in River Cree

3.2.1 Background

Information was presented at the VM1 meeting regarding the performance of this option, this was based on a 1:200 year return period event. A consensus was reached that further information was needed for lower return period events.

3.2.2 Specific Assessment Methodology Details

10 weirs were added to the river reach in a cascade-type sequence upstream of Newton Stewart to simulate obstructions to the flow. The heights of these weirs were 60% of the channel height at their respective locations, and their impact has been assessed within the hydraulic model.

3.2.3 Hydraulic Modelling Findings

Output from the hydraulic model showed there to be a positive impact on flood risk through application of this option; the impact was found to be minimal. Presence of the weirs yielded a reduction in peak flows of $27m^3/s$ at the 200-year return period event. This translated to a maximum reduction in water depth at the 200-year event of 60mm at the town. The overall flood outline was shown to be smaller, however the numbers of receptors inundated was not reduced.

The 1:200 year return period modelling output for the option is presented in Figure 3-3.

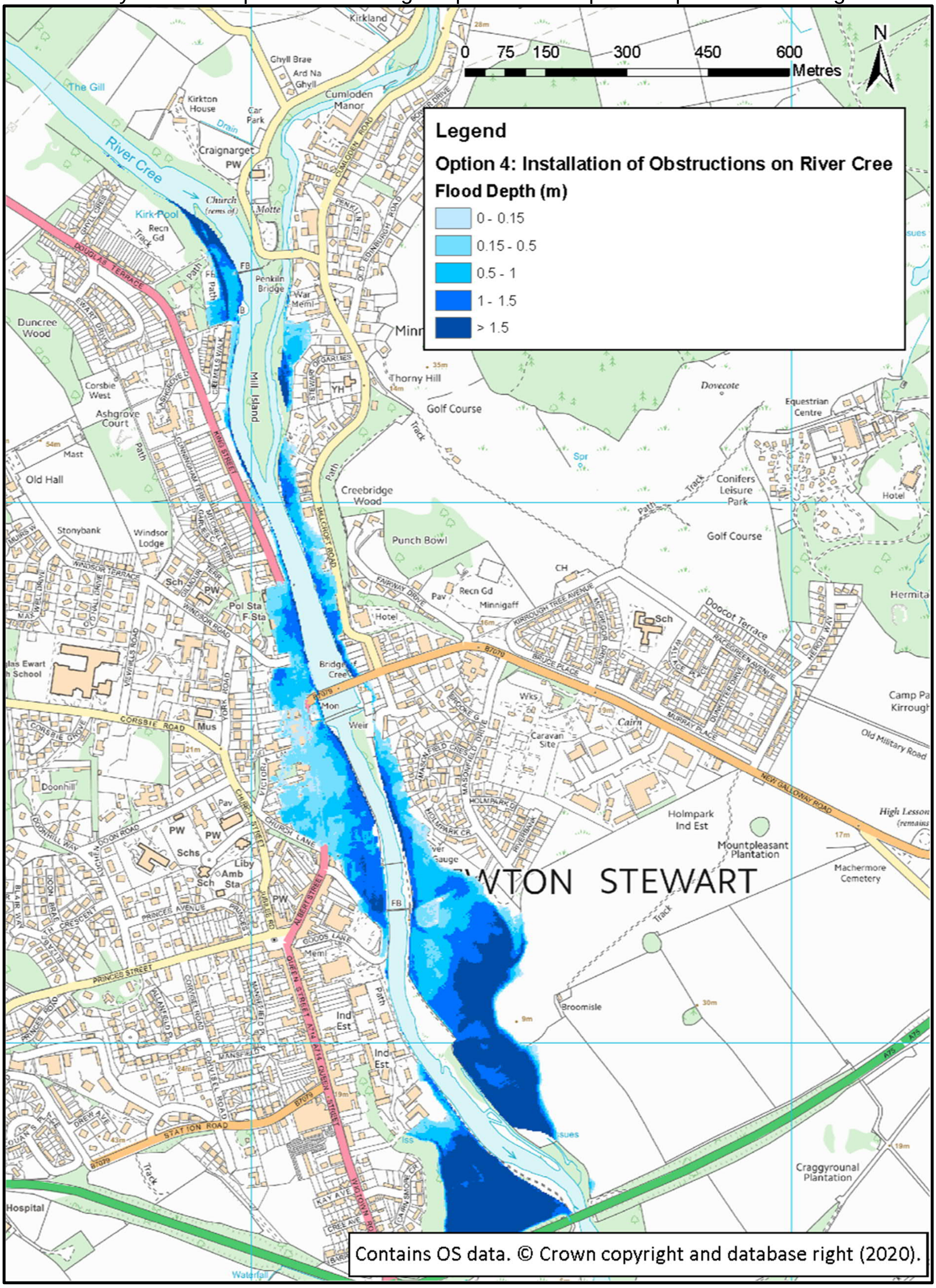

Figure 3-3 - Installation of Obstructions on the River Cree - 1:200 Year Predicted Outline

3.2.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option have been presented in Table 3-2.

Table 3-2 - Installation of Obstructions on the River Cree - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries, sand and gravel pits	**Low**
Unconfirmed mine shafts – condition unknown	**Medium**
Proximity to Wood of Cree SSSI	**Low**
Proximity to Galloway Oaklands SAC	**Low**
Protected species designations for freshwater fish	**Medium**
Potential for uncharacterised made ground	**Low**
Potential mineral instability relating to mine shaft	**Low**
Uncertainty regarding foundation material for potential structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.2.5 Cost-Benefit Findings

Because there was no reduction in the numbers of receptors, and due to the discussed negative impact on local ecology, a cost-benefit calculation was not carried out for this option.

3.2.6 Feedback from Stakeholders

Dumfries & Galloway Council noted that SEPA are (in general) in the process of removing weirs within rivers rather than providing new ones.

Reference was again made to the Sparling fish, a protected species which would be adversely impacted by an intervention of this nature. This is because engineering within the river to create a barrier could impede their movement upstream. Any work of this type would be required to contain measures to mitigate any effects on the Sparling fish. A CAR license would be needed to carry out work of this nature, and it was considered that there is a high risk in this case that such a license may not be granted.

3.2.7 Decision

This option was removed from consideration. This was based on the minimal reduction in flows that it would provide in combination with the high risk to local ecology.

3.3 Option 6: Construction of Direct Defences

3.3.1 Background

The provision of direct defences was considered on the short-list in multiple locations. The five scenarios assessed, as shown in Figure 3-4, were:

- South-west;
- North-west;
- South-west & north-west;
- South-west, north-west & south-east; and
- All areas.

Direct defences could be constructed as mass concrete retaining walls, reinforced concrete retaining walls, sheet piling, bored piling, masonry walls or earth bunds. The appearance of direct defences would be in keeping with the look of the existing local area.

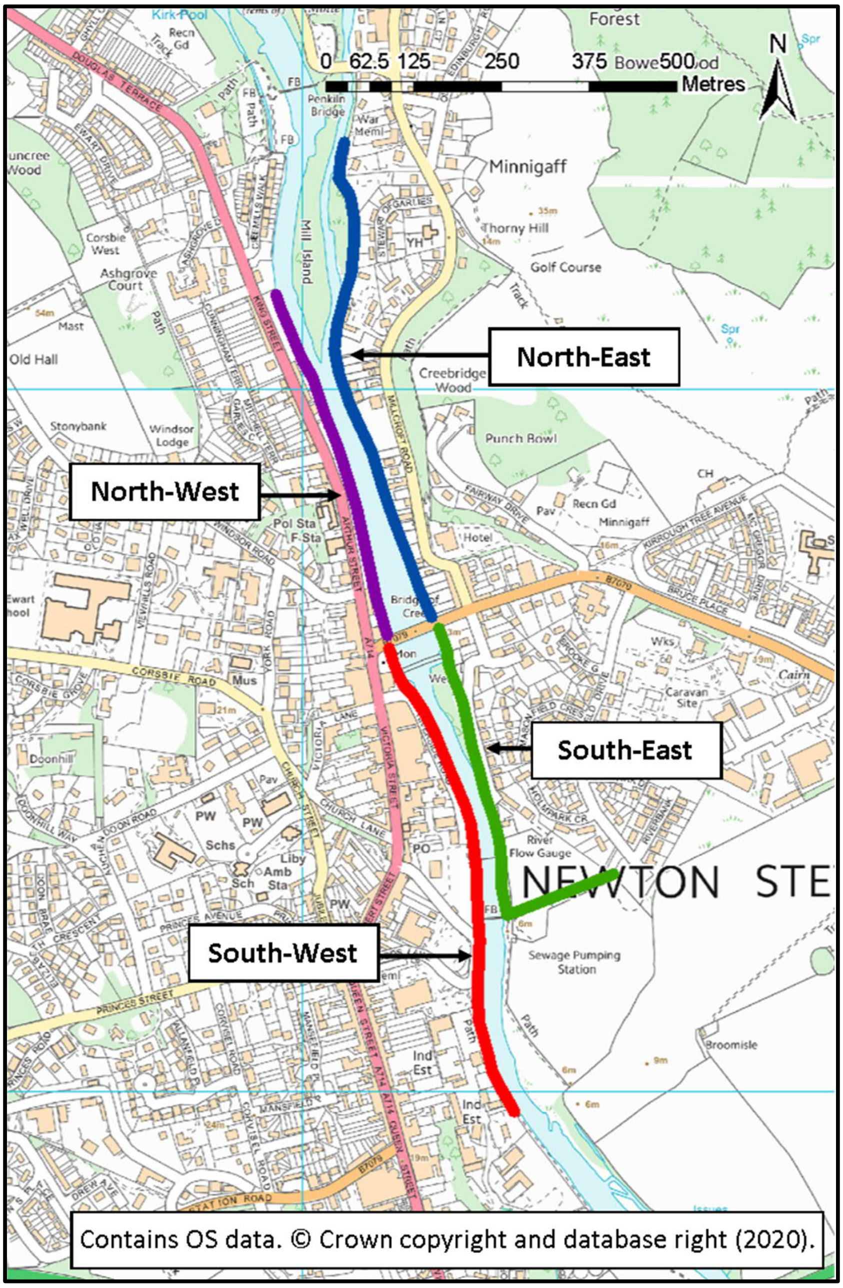

Figure 3-4 - Potential Locations for Direct Defences

3.3.2 Specific Assessment Methodology Details

The flood wall was represented within the hydraulic model by an infinitely high barrier. This was created by removing link lines between the 1D and 2D zones, thus meaning no water could leave the river channel at the desired locations.

3.3.3 Hydraulic Modelling Findings

The findings from the modelling for each sub-option have been presented here, each in turn.

South-West Area

Modelling of this option has indicated that direct defences in the south-western part of the town would not provide adequate protection. The hydraulic model predicts that water will reach the defended area through overland flow paths, thus bypassing the defence itself. Due to the change in flow dynamics across the floodplain, construction of defences in this area alone would increase the number of flooded receptors from 133 (at present) to 144 at the 1:200 year event. The predicted flood outline for the option, along with indicative siting location of direct defences, is presented in Figure 3-5.

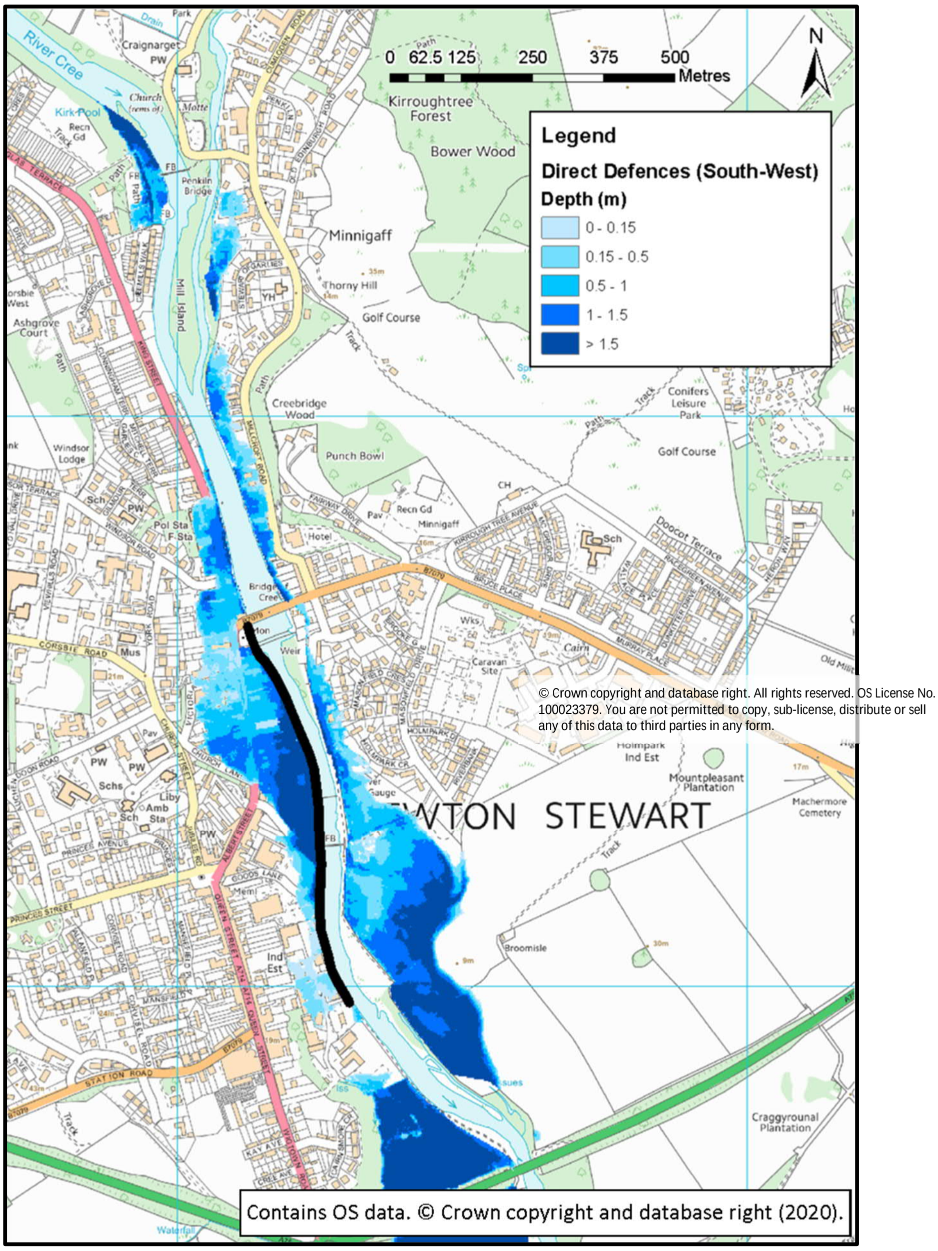

Figure 3-5 - Provision of Direct Defences in South-West - 1:200 Year Predicted Flood Outline

North-West Area

The predicted flood outline for this option, along with indicative siting location of direct defences, has been presented in Figure 3-6. Defences in the north-western area protect the land behind them; with the number of flooded receptors found to reduce from 133 (at present) to 99 at the 1:200 year event. Thus, a small level of improved protection to the town is provided by this configuration of direct defences.

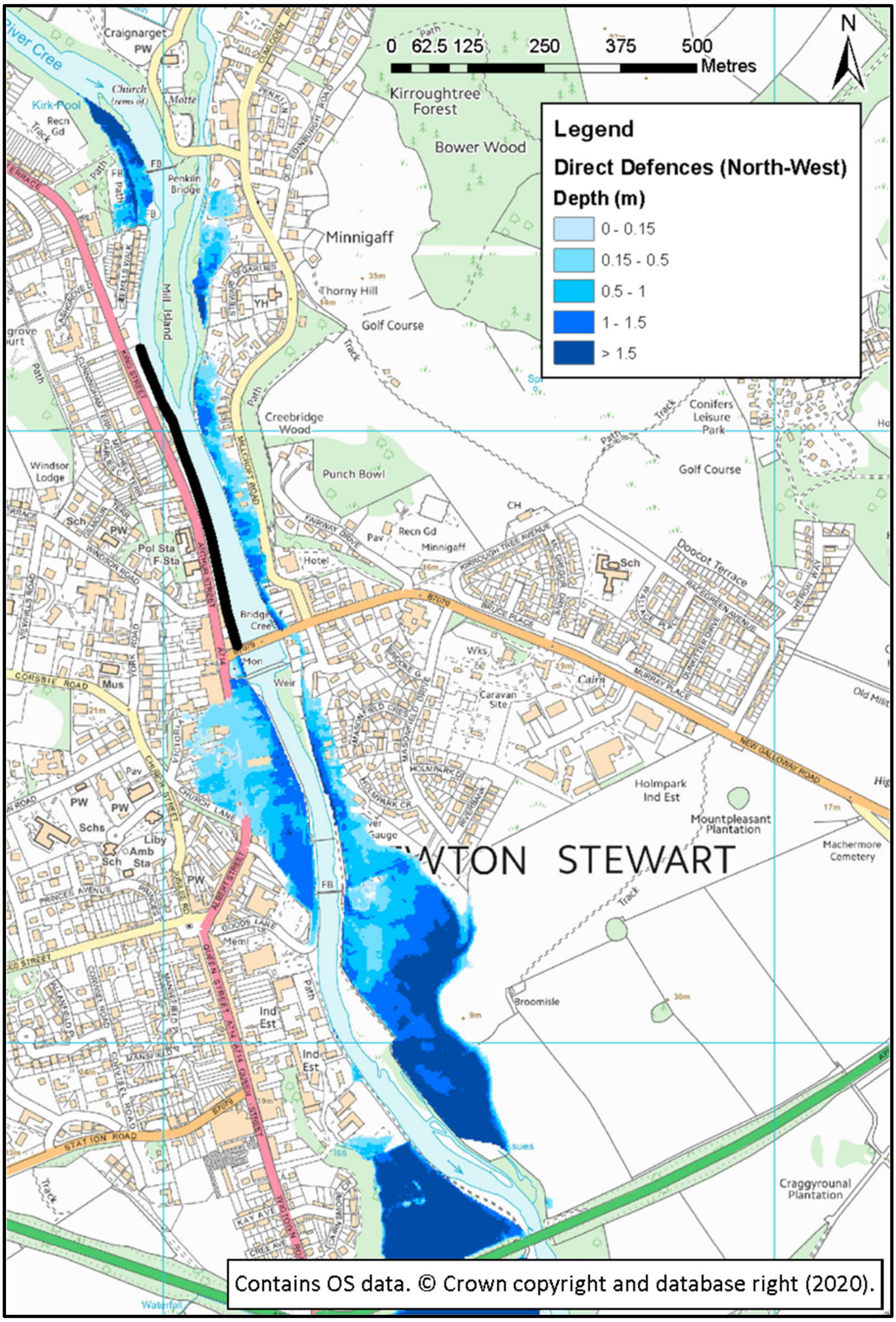

Figure 3-6 - Provision of Direct Defences in North-West - 1:200 Year Predicted Flood Outline

South-West & North-West Areas

Hydraulic modelling predicts that the walls sited on the western bank of the River Cree could reduce the number of flooded receptors from 133 (at present) to 27. Therefore, a significant positive impact on flood risk within the town could be provided via this option. The 1:200 year flood outline for this option is shown on Figure 3-7. Increases in flood levels (at the 1:200 year return period event) of up to 100mm at existing receptors were predicted on the east side, with no new receptors brought into risk. Implementation of this option would be conditional on mitigation works being carried out to ensure no increase in water level on the eastern riverside.

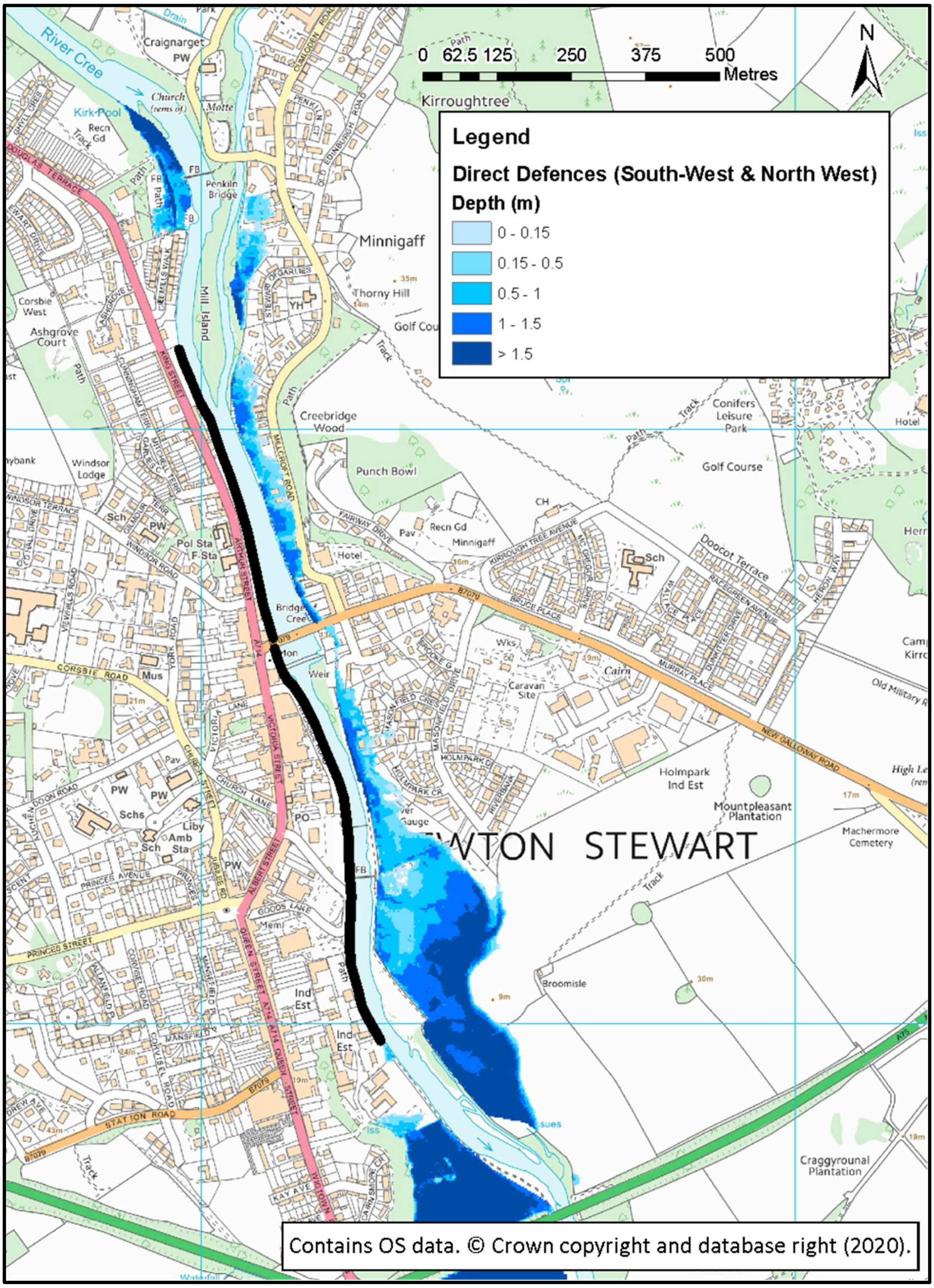

Figure 3-7 - Provision of Direct Defences in South-West & North-West - 1:200 Year Predicted Flood Outline

South-West, North-West & South-East Areas

Direct defences in these areas, as shown in Figure 3-8, are predicted to reduce the number of flooded receptors from 133 (at present) to 20 at the 1:200 year return period event. Therefore, a significant positive impact on flood risk within the town could be provided via this option. Increases in flood levels (at the 1:200 year return period event) of up to 100mm at existing receptors were predicted in the north-east of the town, with no new receptors brought into risk. Implementation of this option would be conditional on mitigation works being carried out to ensure no increase in water level on the north-eastern riverside.

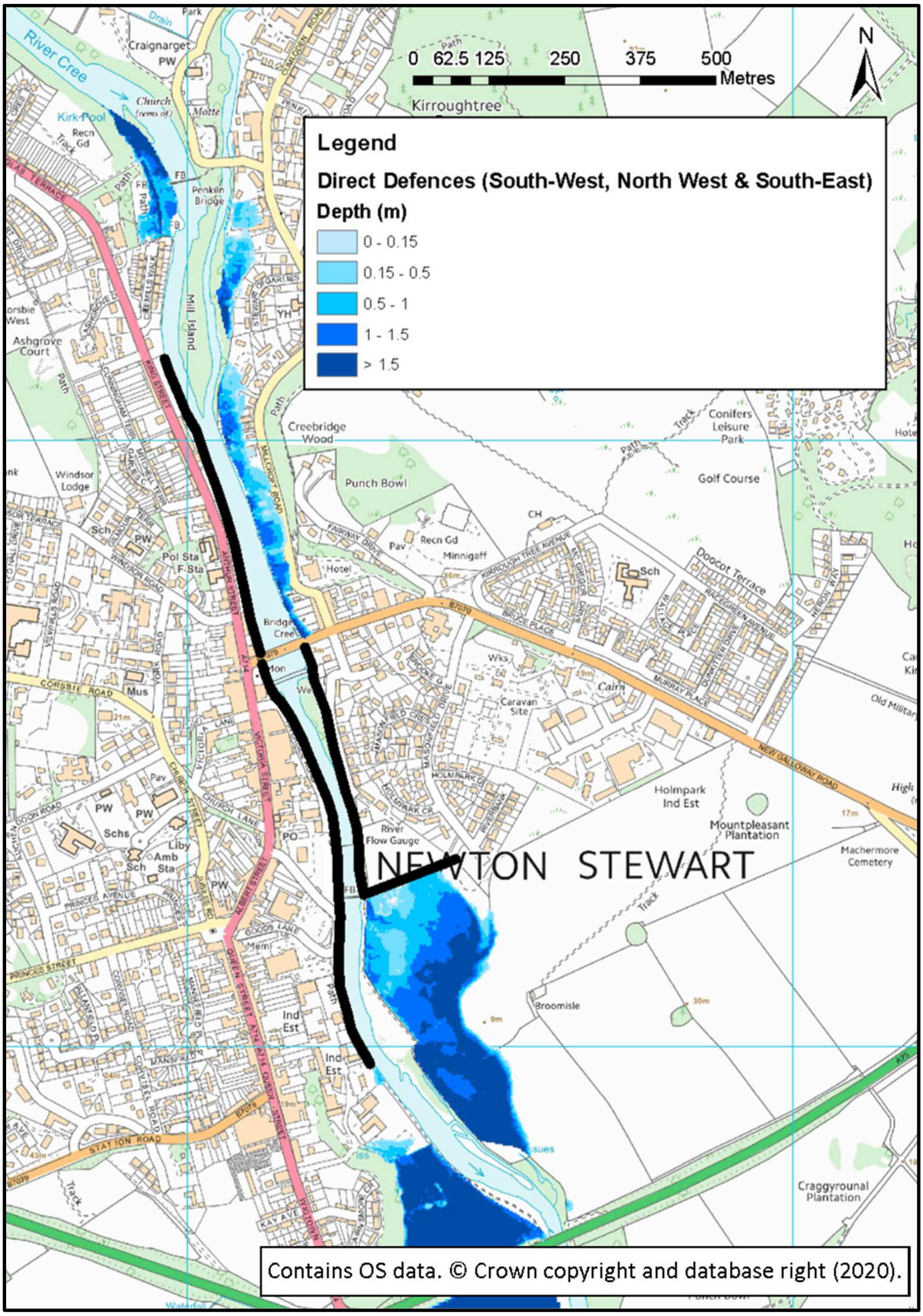

Figure 3-8 - Provision of Direct Defences in South-West, North-West & South-East - 1:200 Year Predicted Flood Outline

All Areas

Direct defences in all areas could reduce the number of flooded receptors from 133 (at present) to 2, at the 1:200 year return period event. Therefore, a significant positive impact on flood risk within the town could be provided via this option. The indicative locations of defences and predicted flood outline can be seen in Figure 3-9. Advanced construction techniques, to install defences in areas of restricted access, may be required.

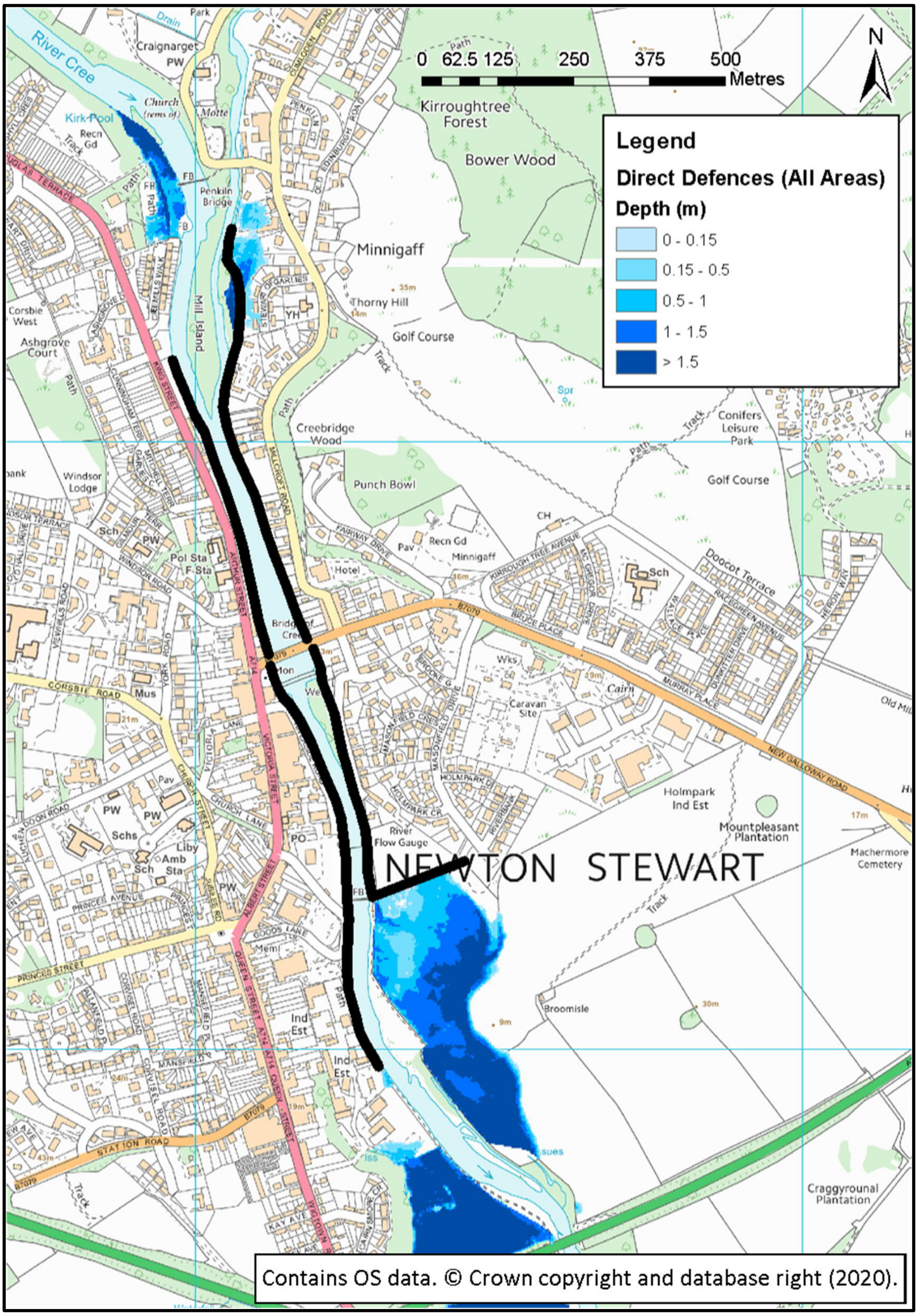

Figure 3-9 - Provision of Direct Defences in All Areas - 1:200 Year Predicted Flood Outline

3.3.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are been presented in Table 3-3.

Table 3-3 - Construction of Direct Defences - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled mill lades	Data
Proximity to former town gasworks site	Low
Proximity to former public slaughterhouse	Low
Proximity to sewage works and pumping station	Low
Proximity to former tannery	Low
Proximity to SEPA identified contaminated land site	Low
Within Newton Stewart conservation area	Medium
Protected species designations for freshwater fish	Medium
Potential for uncharacterised made ground	Low
Steep slopes	Medium
Uncertainty regarding foundation material for structures	Low
Potential for compressible materials to be present in situ	Low

3.3.5 Cost-Benefit Findings

Table 3-4 presents the benefit-cost ratio for each of the direct defence options considered. A clear positive case for funding (BCR = 1.24) was found where defences were placed in the south-west *and* north-west areas of the town. An optimism bias of 60% was applied to the BCR calculations.

Table 3-4 - BCR Findings for Construction of Direct Defences

Defence Location	BCR
South-West	0.62
North-West	0.84
South-West & North-west	1.24
South-West, North-West & North-East	0.86
All Areas	0.68

3.3.6 Feedback from Stakeholders

Having been presented with the BCR values, CVCC expressed concern that defences would only be available on one side of the river. This led to discussion on how the whole town could be defended, and assurances that no scheme would leave any part of Newton Stewart at a detriment in comparison with the baseline case. CVCC provided information regarding a historical wall that existed (approx. 1m in height) on the Minnigaff side of the river.

It was agreed by all stakeholders that the concept of direct defences would protect the greatest number of households in Newton Stewart.

3.3.7 Decision

This option was progressed to the outline design stage, considering the high number of receptors that could be protected and due to the finding that at least one configuration yielded a positive case for funding.

3.4 Option 7: Increase Flow Area Beneath A75T Bridge

3.4.1 Background

The flow area beneath the A75T bridge can be increased by reducing the level of the land on which footpaths and scrubland is currently situated, as shown in Figure 3-10. The cycle path, to the right of this image, is noticeably raised. Figure 3-11 illustrates the impact of the raised ground at this location in times of flooding. The image has been captured looking upstream from the top of the A75T bridge. The same sign indicating shared pedestrian pathway and cycle path can be seen in both images.

To facilitate the increased flows, a two-stage channel would be constructed upstream of the bridge. The cycle path would be reinstated at a lower elevation and hence will flood during any storm event that may inundate the town.

Figure 3-10 - View Beneath A75T Bridge Looking Downstream

Figure 3-11 - View Beneath A75T Bridge Looking Upstream from Bridge Deck During Flood

3.4.2 Specific Assessment Methodology Details

Approximately 10m of additional width could be gained beneath the A75T bridge on each bank, based on observations made on site visits. Within the model, ground was lowered to a level of 5.2mAOD which does not fill with water under normal flow conditions but would provide additional capacity during extreme events. This cut was extended within the model 400m upstream of the bridge to route additional flow beneath the bridge from the town.

3.4.3 Hydraulic Modelling Findings

Modelling predicted an increase in flow capacity of 35m^3/s through the A75T bridge as a result of this intervention. Although water levels were found to decrease in the town, this option did not reduce the number of receptors at the 1:200 year event. This intervention could be used as mitigation to optimise the preferred option. The 1:200 year flood outline for this option can be seen in Figure 3-12. Design and construction of this intervention would need to account for the protected species of fish present at this location in the designated SSSI area to the east side of the bridge.

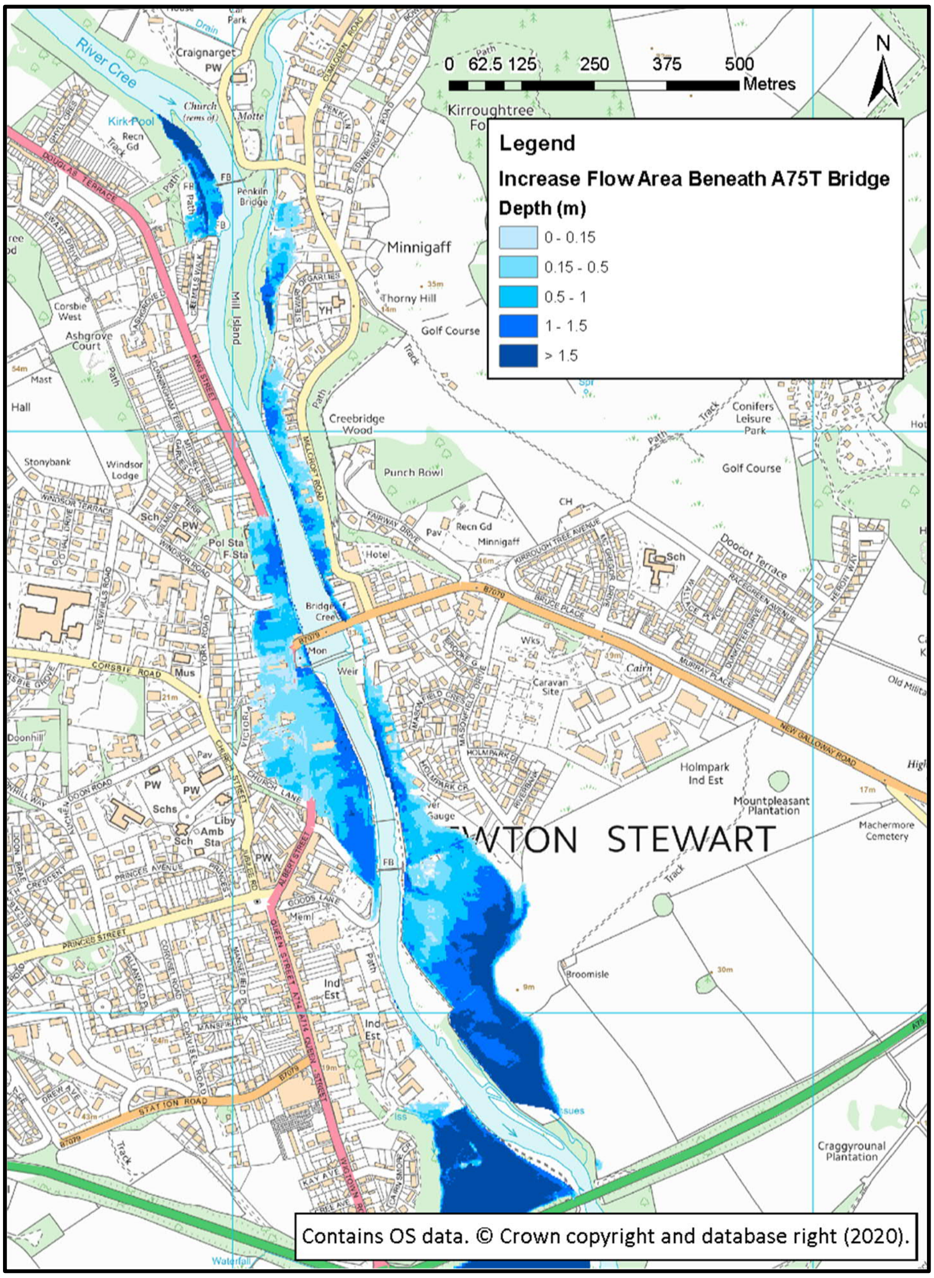

Figure 3-12 - Increase Flow Area Beneath A75T Bridge - 1:200 Year Predicted Flood Outline

3.4.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are presented in Table 3-5.

Table 3-5 - Increase Flow Area Beneath A75T Bridge - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries and gravel pits	**Low**
Proximity to former public slaughterhouse	**Low**
Within Lower River Cree SSSI	**Medium**
Protected species designations for freshwater fish	**Medium**
Potential for uncharacterised made ground	**Low**
Steep slopes	**Medium**
Uncertainty regarding foundation material for structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.4.5 Cost-Benefit Findings

The cost-benefit ratio of this option was found to be 9.84 although this figure should be used with caution. Flood damages were reduced by reducing the flood depth in receptors, rather than taking them out of flood risk altogether. Combining this with minimal capital investment has resulted in a strong case for funding. This option should be used in conjunction to optimise the preferred option – rather than as a standalone solution.

3.4.6 Feedback from Stakeholders

CVCC commented that the A75T embankment appeared to be a large barrier to flow and were surprised that the option did not yield even greater benefit. They were, overall, supportive of the idea. Stakeholders in general agreed with the concept of providing greater flow area for water to drain downstream more easily, but provided a reminder of the SSSI near to the location. It was accepted that this constraint may limit what work could be done here.

3.4.7 Decision

It was decided to progress with this option due to its high BCR and simple construction methodology. As it was clear the option would not work alone, its progression was conditional on it being combined with another selected option.

3.5 Option 9: Increase A75T Flood Relief Culvert Size/Number

3.5.1 Background

This option considered upsizing and/or providing additional flood relief culverts through the A75T embankment, on the western floodplain of the Cree. Three scenarios were tested:

- **Option 9a:** 1x additional flood relief culvert beneath A75T embankment;
- **Option 9b:** 2x additional flood relief culverts beneath A75T embankment; and
- **Option 9c:** 2x additional flood relief culverts beneath A75T embankment *and* upsizing of all culverts

3.5.2 Specific Assessment Methodology Details

Local topography was modified in the model to provide overland pathways from the river bank to the flood relief culverts.

3.5.3 Hydraulic Modelling Findings

Modelling predicted no reduction in the number of receptors resulting from the addition of new, or upsizing of existing, flood relief culverts. The associated 200-year return period flood map are presented in Figure 3-13. Despite the provision of overland pathways to convey flow from the river towards the flood relief culverts, the topography still caused water in the river to rise during storms. During extreme events it was found that the culverts became drowned, preventing them from providing flood risk reduction.

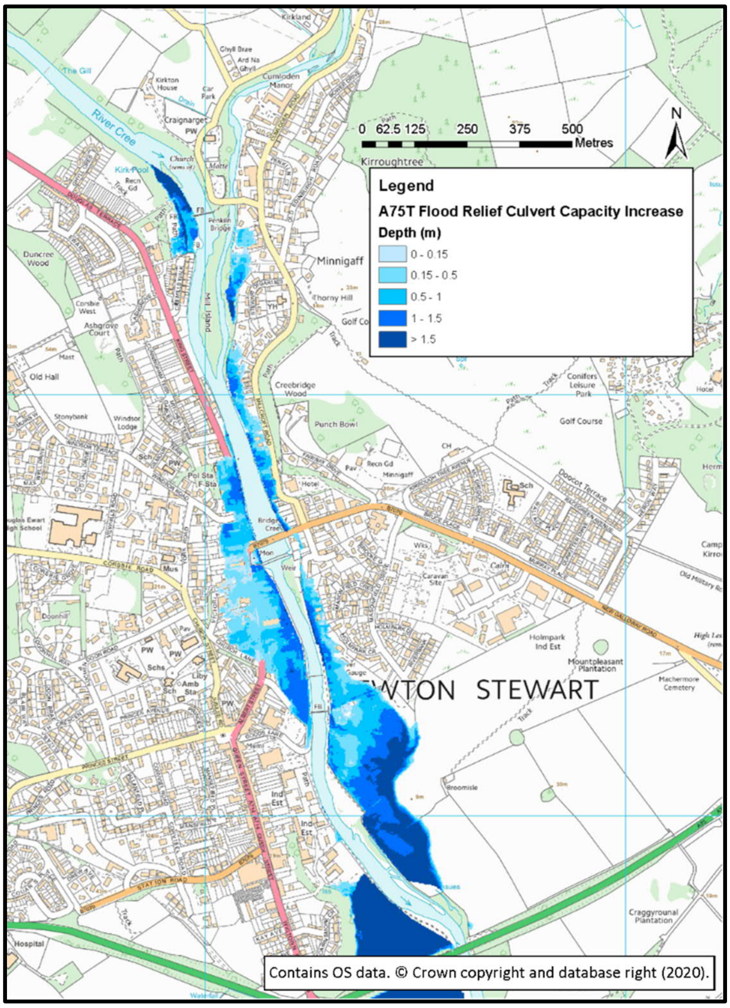

Figure 3-13 - Increase A75T Flood Relief Culvert Capacity / Number - 1:200 Year Predicted Flood Outline

3.5.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option have been presented in Table 3-6.

Table 3-6 - Increase A75T Flood Relief culvert Capacity / Number - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries and gravel pits	Low
Proximity to former public slaughterhouse	Low
Within Lower River Cree SSSI	Medium
Protected species designations for freshwater fish	Medium
Potential for uncharacterised made ground	Low
Steep slopes	Medium
Uncertainty regarding foundation material for structures	Low
Potential for compressible materials to be present in situ	Low

This option would require complex geotechnical work within the embankment itself; which comes with risks to i) the construction programme; and ii) operation of the active A75T road.

3.5.5 Cost-Benefit Findings

The cost benefit analysis results for this option are low. A BCR of 0.31 was obtained for the addition of 1 additional flood relief culvert, 0.24 for the addition of 2 flood relief culverts and 0.14 for the addition of 2 culverts *and* the upsizing of all existing ones. The low values seen here are reflective of the minimal impacts of the option.

3.5.6 Feedback from Stakeholders

Kaya Consulting highlighted the additional need in this area to consider the effects of the tide. The CVCC also commented on this effect, noting that the town was lucky that during the 2015 flood event the high tide occurred approximately one hour after the peak flow. This was subsequently investigated and found to be inconsequential to the design.

3.5.7 Decision

It was decided not to progress with this option due to the limited impact that the concept had been shown to have on flood levels in the town. It was agreed that the A75T embankment does provide an obstruction to flow, however that the option of providing greater flow area beneath the bridge was much more effective than adding new flood relief culverts.

3.6 Option 19: Re-profile Land at Broomisle

3.6.1 Background

This option sought to reduce ground levels in the Broomisle area, providing additional flood storage. The additional storage area was investigated because it was thought that it could mitigate the backing-up of the River Cree that results from the embankment in the floodplain.

3.6.2 Specific Assessment Methodology Details

The ground data within the hydraulic model was modified in the area shown on Figure 3-14. Ground levels in this area, where they were less than 10mAOD, were reduced to a level of 6mAOD (if they were not already below this level).

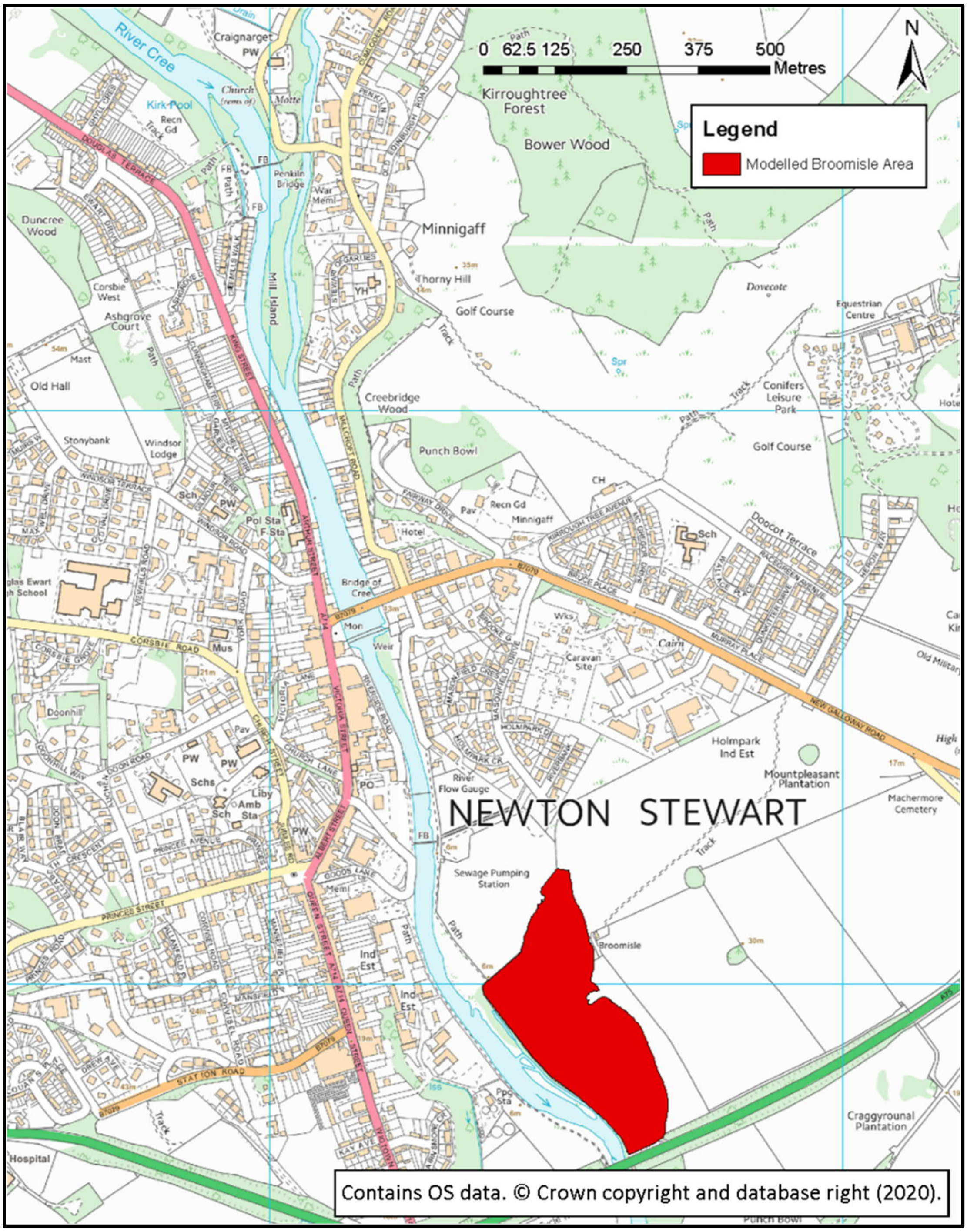

Figure 3-14 - Reprofile Land at Broomisle - Area Modelled

3.6.3 Hydraulic Modelling Findings

This option did not reduce the number of receptors impacted. The hydraulics of the river and floodplain at Broomisle were such that, for extreme events, the area filled with water during the earlier stages of the storm and thus later had no impact on the peak. The 1:200 year return period event flood map is shown in Figure 3-15.

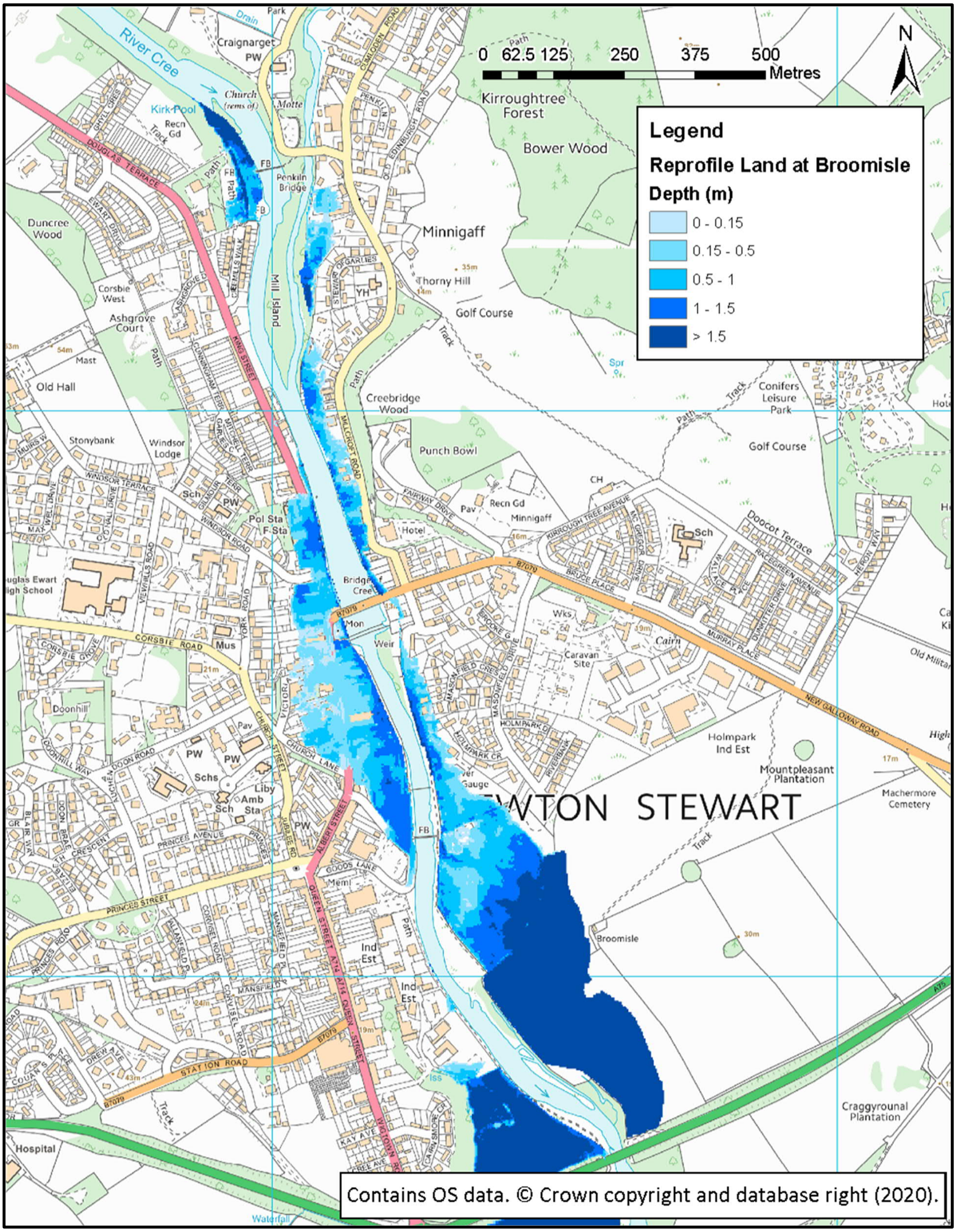

Figure 3-15 - Reprofile Land at Broomisle - 1:200 Year Predicted Flood Outline

3.6.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are presented in Table 3-7.

Table 3-7 - Reprofile Land at Broomisle - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries and gravel pits	**Low**
Proximity to former public slaughterhouse	**Low**
Within Lower River Cree SSSI	**Medium**
Protected species designations for freshwater fish	**Medium**
Potential for uncharacterised made ground	**Low**
Steep slopes	**Medium**
Uncertainty regarding foundation material for structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.6.5 Cost-Benefit Findings

The BCR for this option was found to be 0.09. This is a result of the very low impact of the modification on flood levels in the town.

3.6.6 Feedback from Stakeholders

Stakeholders commented that this area is already subject to flooding and that any further modification is unlikely to provide any benefit to the town.

3.6.7 Decision

This option was not progressed, due to having no material improvement on flood risk throughout the town.

3.7 Option 20: Reinstate Flood Storage Area at Water of Minnoch

3.7.1 Background

This option was discussed at the VM1 meeting, it was decided that a high-level modelling exercise will be used to identify whether storage at this location could be beneficial.

3.7.2 Specific Assessment Methodology Details

A level of uncertainty was associated with this option, as reports referred to a historical feature that is no longer operational. An impoundment was modelled in the upper catchment at 237678 E, 576135 N, and was oriented to optimise the volume. This storage volume was approximately 500,000m^3, however this required a dam that would be 229m wide and approximately 14m in height (based on local topography). As a proof of the concept, the modelling was progressed with this configuration. Following discussion with SEPA, a further model run with a dam height of 2m was carried out. This was considered more practical and in-line with local topography.

3.7.3 Hydraulic Modelling Findings

This option was found to have a positive influence on flood risk, however the extent of this influence varied across return periods. At return periods of 1:10 years (and more frequent) the number of receptors within the town was found to be minimal following implementation of this option. However, events of greater magnitude associated with higher return periods (e.g. 1:100, 1:200) were still found to affect the town extensively even with implementation of the options. For example, modelling output for the 1:200 year event is shown in Figure 3-16. Modelling results for the dam height of 2m yielded no effect on the numbers of receptors impacted in the town, as the storage area filled up quickly early in the storm.

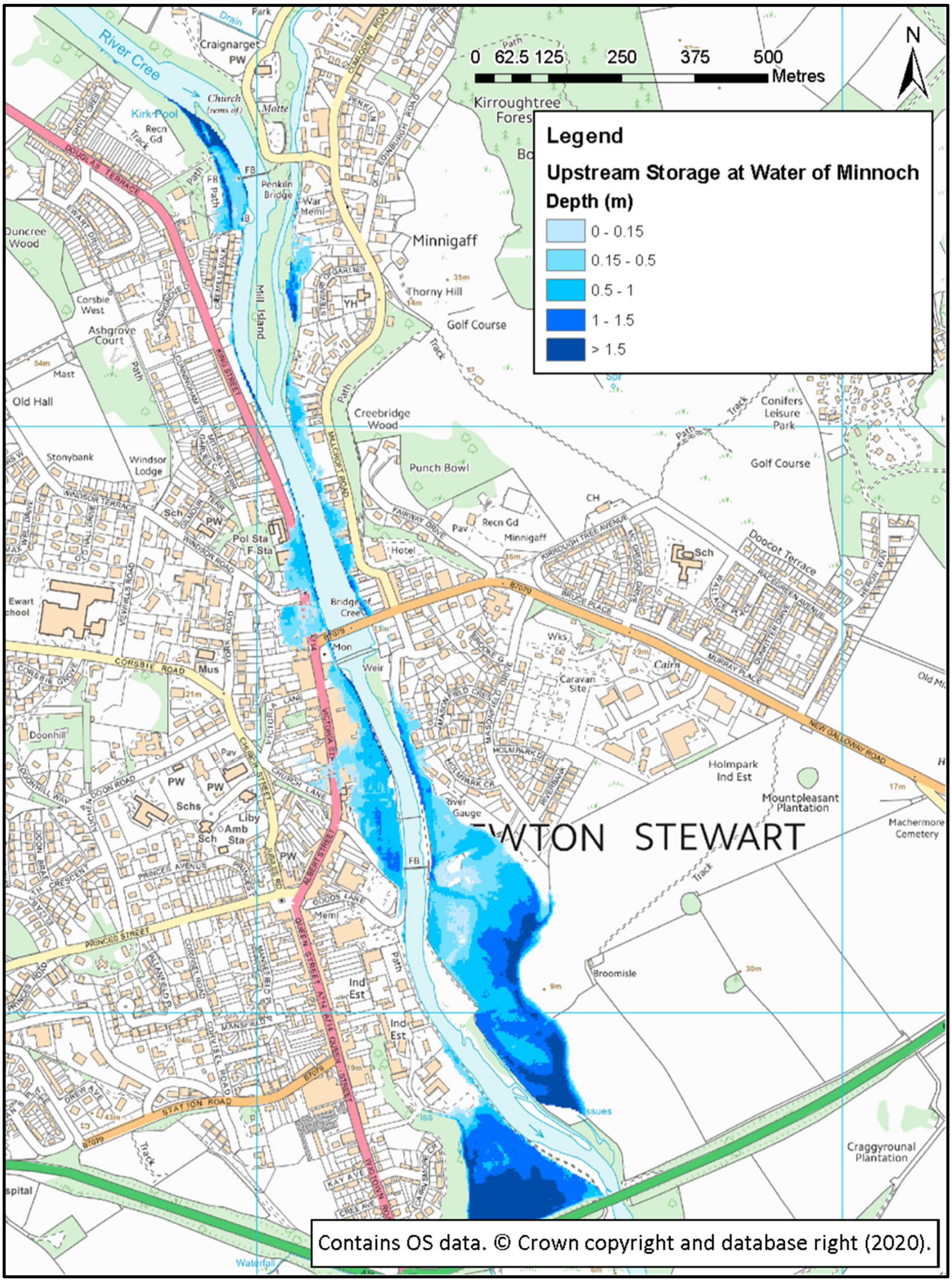

Figure 3-16 - Upstream storage at Water of Minnoch - 1:200 Year Predicted Flood Outline

3.7.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are presented in Table 3-8.

Table 3-8 - Upstream Storage at Water of Minnoch - Geo-Environmental Constraints

Constraint	Impact
Protected species designations for freshwater fish	**Medium**
Uncertainty regarding foundation material for structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.7.5 Cost-Benefit Findings

The benefit-cost ratio was not calculated given the low impact on receptors and low constructability of the structure required to yield the minimal results obtained.

3.7.6 Feedback from Stakeholders

SEPA have commented that the structure within the model demonstrates that the option is impractical, and have requested a further hydraulic model run with a more realistic structure in place. It was accepted that the modelling results presented here show an excessively optimistic scenario, and hence the results are sufficient to prove that the concept of impoundment in this area may be discounted as an option.

3.7.7 Decision

The minimal impact of this option, and construction difficulties contributed to the decision not to progress with this option.

3.8 Option 21: Upstream Storage Area at The Ghyll

3.8.1 Background

This option was discussed at the VM1 meeting and it was decided, considering the potential for large storage volumes, that the option should be modelled.

3.8.2 Specific Assessment Methodology Details

Two cases were modelled, where an impoundment was provided to a height of 26mAOD and to a height of 30mAOD. A guide to these areas is shown in Figure 3-17, where the associated footprints are significantly different. The 26mAOD (approximately 4m high impoundment) impoundment provided around 1.1 million m^3 storage, with the 30mAOD (approximately 8m high impoundment) impoundment providing around 10 million m^3 storage.

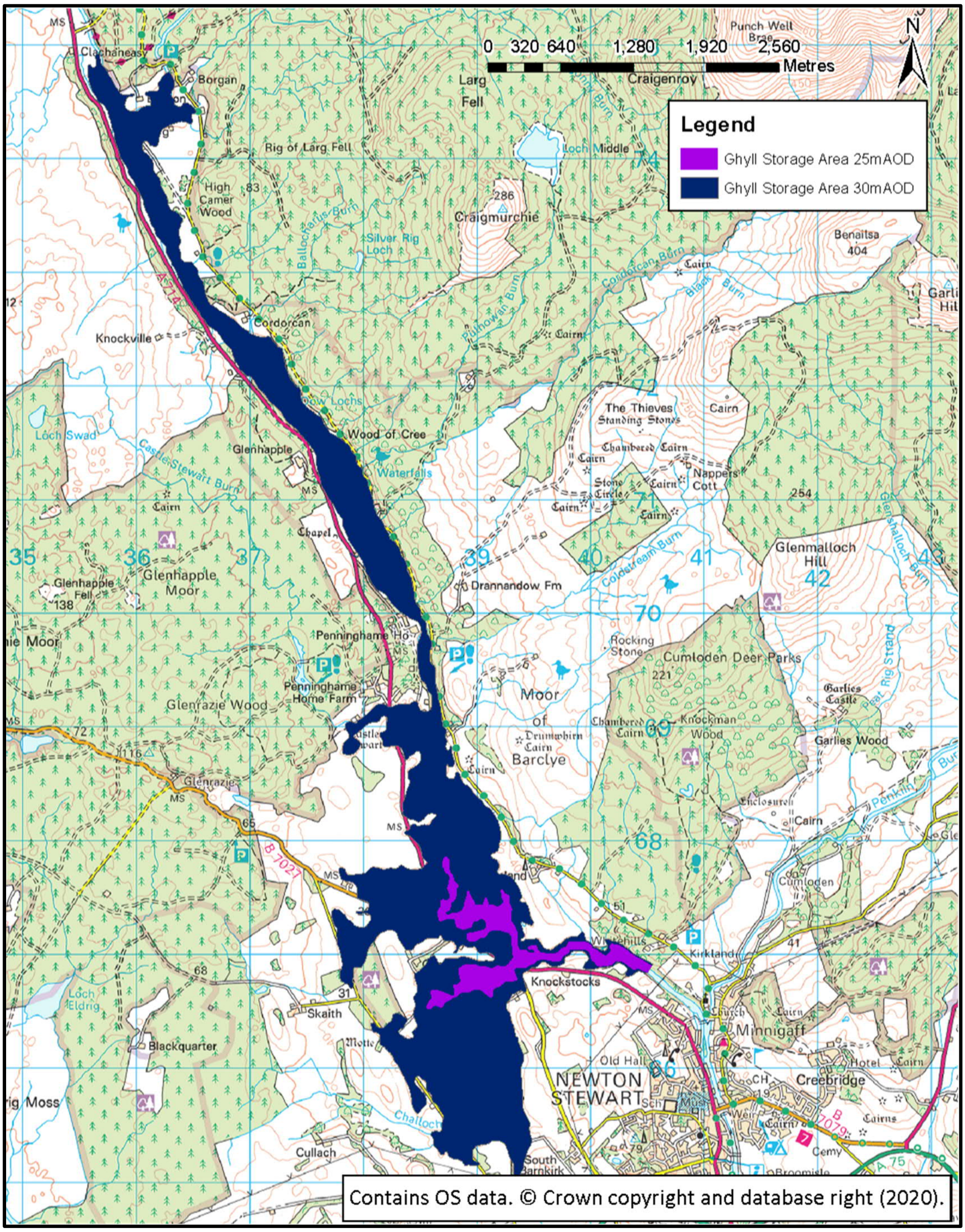

Figure 3-17 - Upstream Storage at The Ghyll - Upstream Inundation Areas

3.8.3 Hydraulic Modelling Findings

Both cases examined showed a positive impact on flood risk in the town in multiple return period events. At the 1:200 year event, the 26mAOD option was seen to significantly reduce the number of receptors inundated, and the 30mAOD option was seen to reduce flood risk within the town to a minimum. Results for these events have been presented in Figure 3-18 and Figure 3-19.

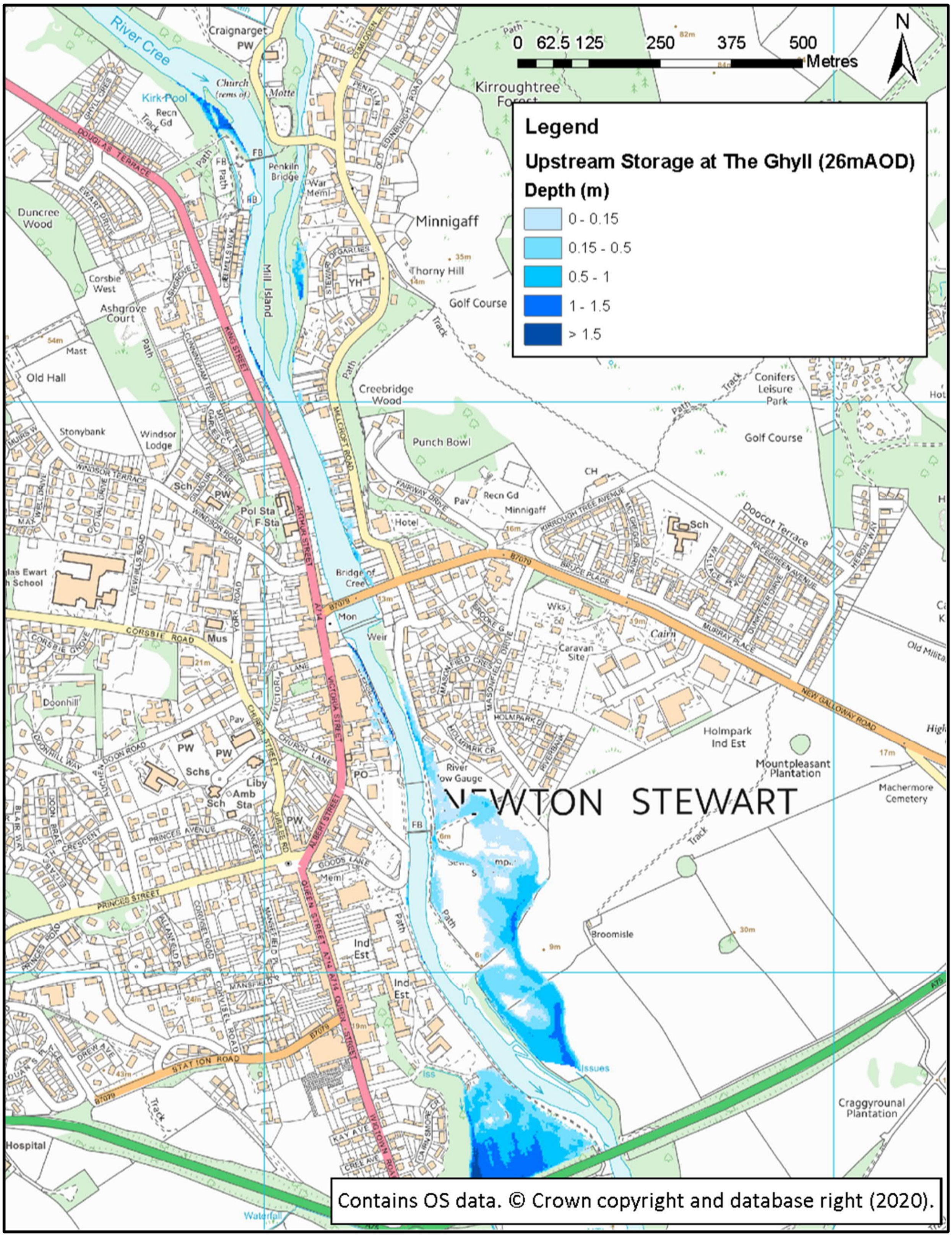

Figure 3-18 – Upstream Storage at The Ghyll (26mAOD), 1:200 Year Return Period Flood Outline

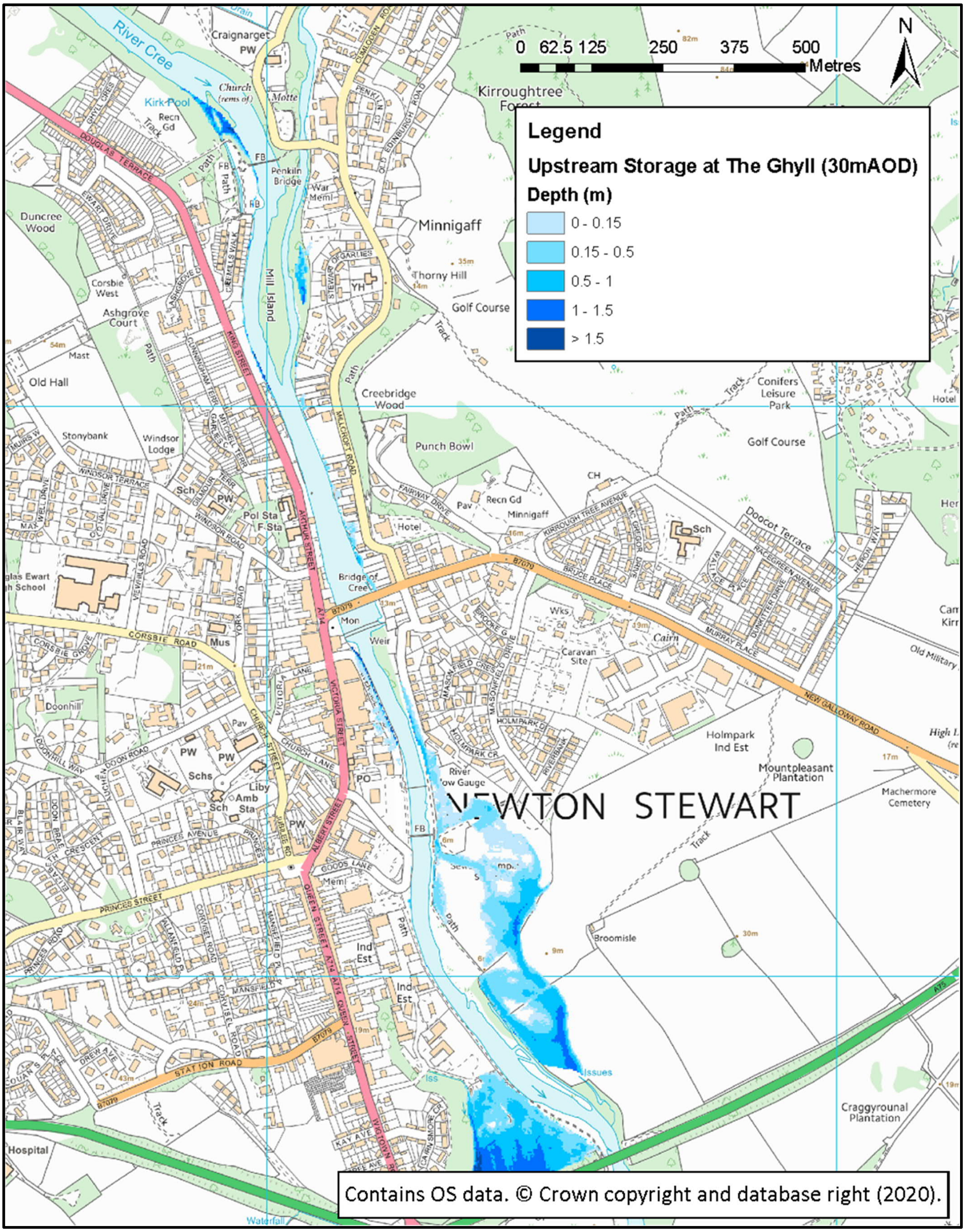

Figure 3-19 – Upstream Storage at The Ghyll (30mAOD), 1:200 Year Return Period Flood Outline

3.8.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option have been presented in Table 3-9.

Table 3-9 - Upstream Storage at The Ghyll - Geo-Environmental Constraints

Constraint	Impact
Potentially infilled quarries, sand and gravel pits	Low
Unconfirmed mine shafts – condition unknown	Low
Former lead mine	High
Proximity to Wood of Cree SSSI	Low
Proximity to Galloway Oaklands SAC	Low
Protected species designations for freshwater fish	Medium
Potential for uncharacterised made ground	Low
Potential mineral instability relating to mine shaft	Low
Uncertainty regarding foundation material for potential structures	Low
Potential for compressible materials to be present in situ	Low

This option contains one constraint that potentially has a high negative impact. The presence of a former lead mine could have serious health and environmental consequences, should this option be implemented. This is because the large area inundated could result in contaminants (lead) being washed downstream, onto pasture and thus into the food chain.

3.8.5 Cost-Benefit Findings

The BCR for the Ghyll storage option was calculated for the 30mAOD (8m high) impoundment as this provided the greatest reduction in flood risk at the town. The BCR for this configuration was found to be 0.54. This reflects the high costs of construction and mitigation works. It should be noted that around 20 properties would need to be purchased for this option to work.

3.8.6 Feedback from Stakeholders

The CVCC commented that the impoundment location that was modelled was not at the location they had envisaged. It was explained that as the location was provided in a descriptive manner, Sweco and Kaya Consulting had found the optimum site for an impoundment near where was described. A model run was additionally made with the impoundment at the location of the former weir, to the upstream of the suspension bridge. The practical height of this at that location was 2m, and at this height water spilled over the impoundment crest in extreme flows. The resulting flood map is shown in Figure 3-20, where it can be seen there is no impact on receptors.

3.8.7 Decision

Based on the significant infrastructure works and the risk of bringing around 20 new properties into flood risk it was decided not to progress with this option.

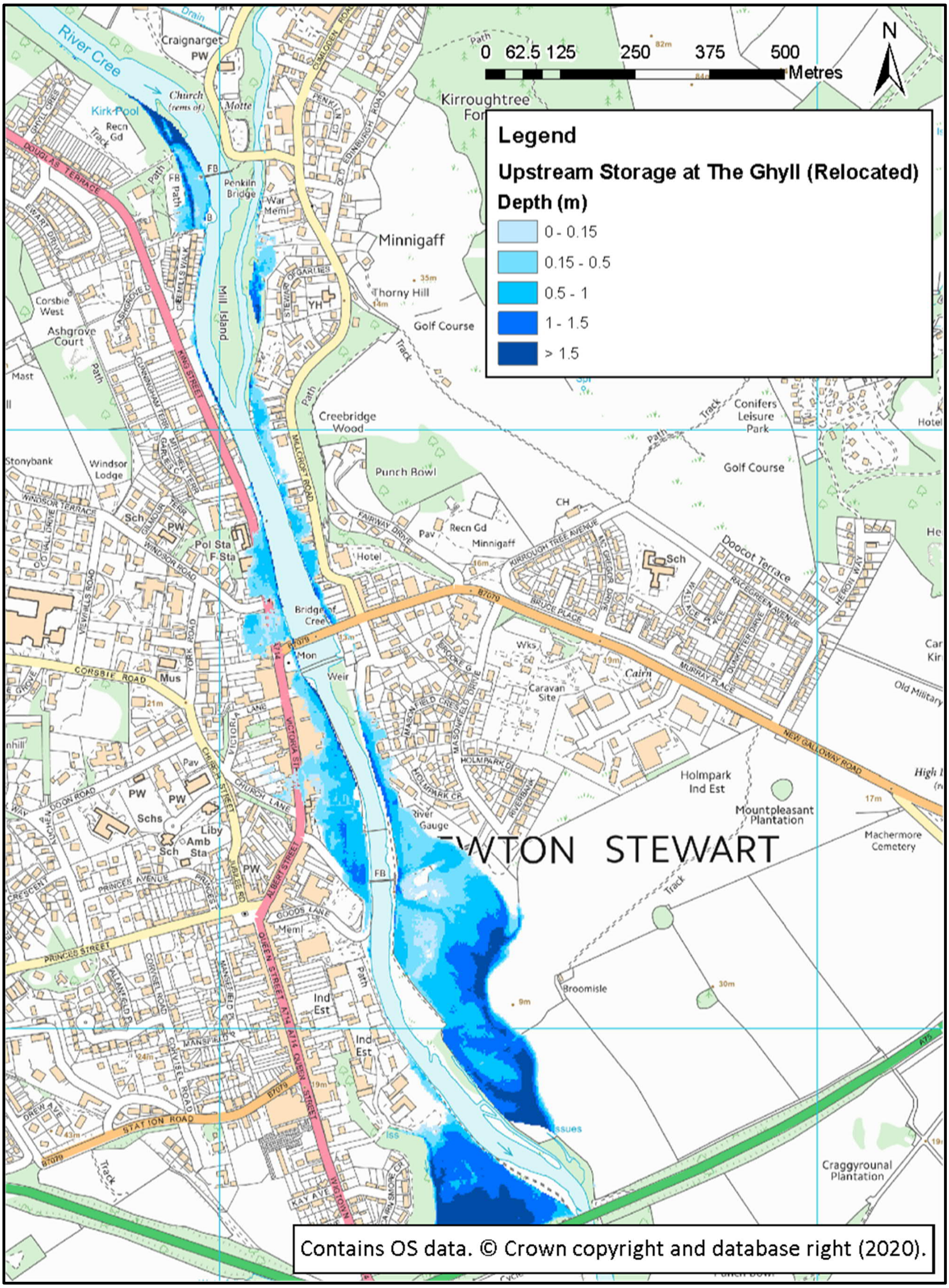

Figure 3-20 - Upstream Storage at The Ghyll - Relocated Impoundment - 1:200 Year Predicted Flood Outline

3.9 Option 22: Upstream Storage in River Cree Tributaries

3.9.1 Background

This option was discussed at the VM1 meeting and was shown not to be feasible in its full form. Hence, it was agreed that a small number of tributaries (7 tested, out of 44 identified as potentially useful) would be impounded to observe the impact on flood levels in the town.

3.9.2 Specific Assessment Methodology Details

Individual hydrological routing models were constructed to model attenuating effects of each impoundment. These were then used with the main River Cree hydrological routing model to consider the overall effect on flow input to the river. Storage volumes at each tributary were estimated from LiDAR and NextMap data; with spill levels assumed to be those at which water would flow over local roads crossing the tributaries.

3.9.3 Hydraulic Modelling Findings

Results from each of the 7 tributaries were similar. There is a lack of storage in the upper catchment resulting from the steep topography. Spill over any given attenuating feature occurs quickly after the storage areas fill. Figure 3-21 shows an example of the response of one of the modelled tributaries (Burnfoot Burn), where the spill plus required base outflow is equal to the non-impounded scenario. Figure 3-22 shows the effect of all 7 tributaries taken into account on the hydrograph on the main River Cree and demonstrates there to be a negligible impact.

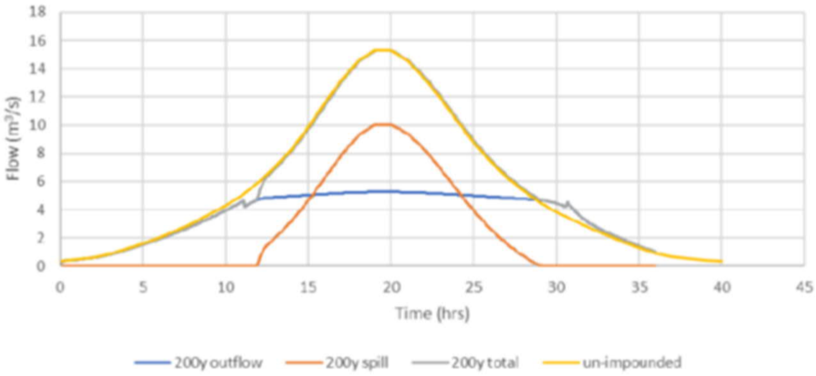

Figure 3-21 - Hydrological Routing at Burnfoot Burn

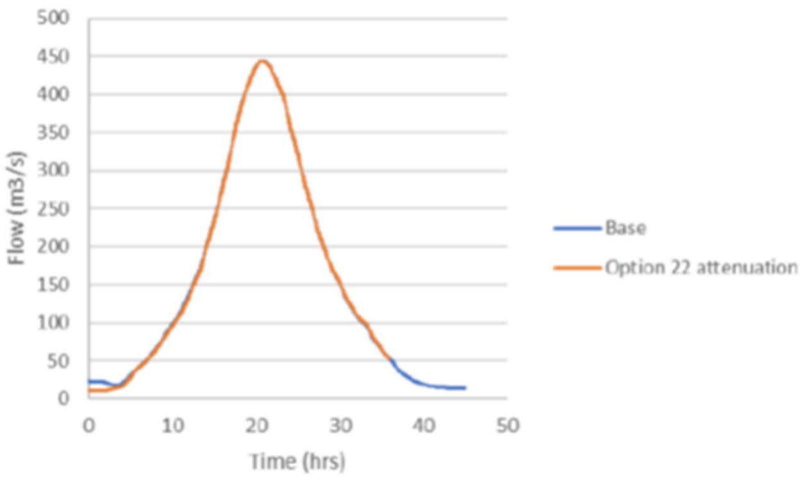

Figure 3-22 - Effects of Attenuation in 7 Tributaries on Overall Flows

3.9.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are presented in Table 3-10.

Table 3-10 - Upstream Storage in Multiple River Cree Tributaries - Geo-Environmental Constraints

Constraint	Impact
Proximity to Glentrool Oakwoods SSSI	**Medium**
Proximity to Galloway Oaklands SAC	**Low**
Protected species designations for freshwater fish	**Medium**
Uncertainty regarding foundation material for potential structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.9.5 Cost-Benefit Findings

Due to the negligible impact on flows, a BCR was not calculated for this option.

3.9.6 Feedback from Stakeholders

CVCC commented that they had envisaged the creation of large lakes and lochs upstream. It was explained that the topography was not conducive to this kind of solution. Discussion then centred on natural flood management (NFM) techniques and how these could be implemented in the catchment. Scottish Water cited a recent Institution of Civil Engineers (ICE) seminar where the numbers of NFM interventions in large catchments was found to be very high. These would take time to implement, and as a result could not be part of the flood scheme itself which is required more urgently. Discussion continued with the Forestry Commission who could support the idea of NFM as part of responsible land management over the long-term.

3.9.7 Decision

Based on the above feedback, attenuation of flows on tributaries of the River Cree was not progressed. It was agreed that the local community, SEPA, SNH, DGC and the Forestry Commission would set-up a forum to discuss how to take this forward over the long-term separately to the flood scheme. A separate report on possible NFM techniques in the upper catchment will be provided by Sweco to inform this group.

3.10 Option 24: Re-profile Land Around Pumping Station

3.10.1 Background

Concerns were raised, at the VM1 meeting, that the construction of a pumping station within the floodplain had resulted in increased flood levels within Newton Stewart. Moving this key piece of infrastructure is not feasible, hence an option to re-profile land around the site was considered.

3.10.2 Specific Assessment Methodology Details

Figure 3-23 shows the extent of land reprofiling considered, where ground levels were lowered to 6mAOD to encourage the overland flow of water away from the western bank. The hydraulic model was then run with this modification in place.

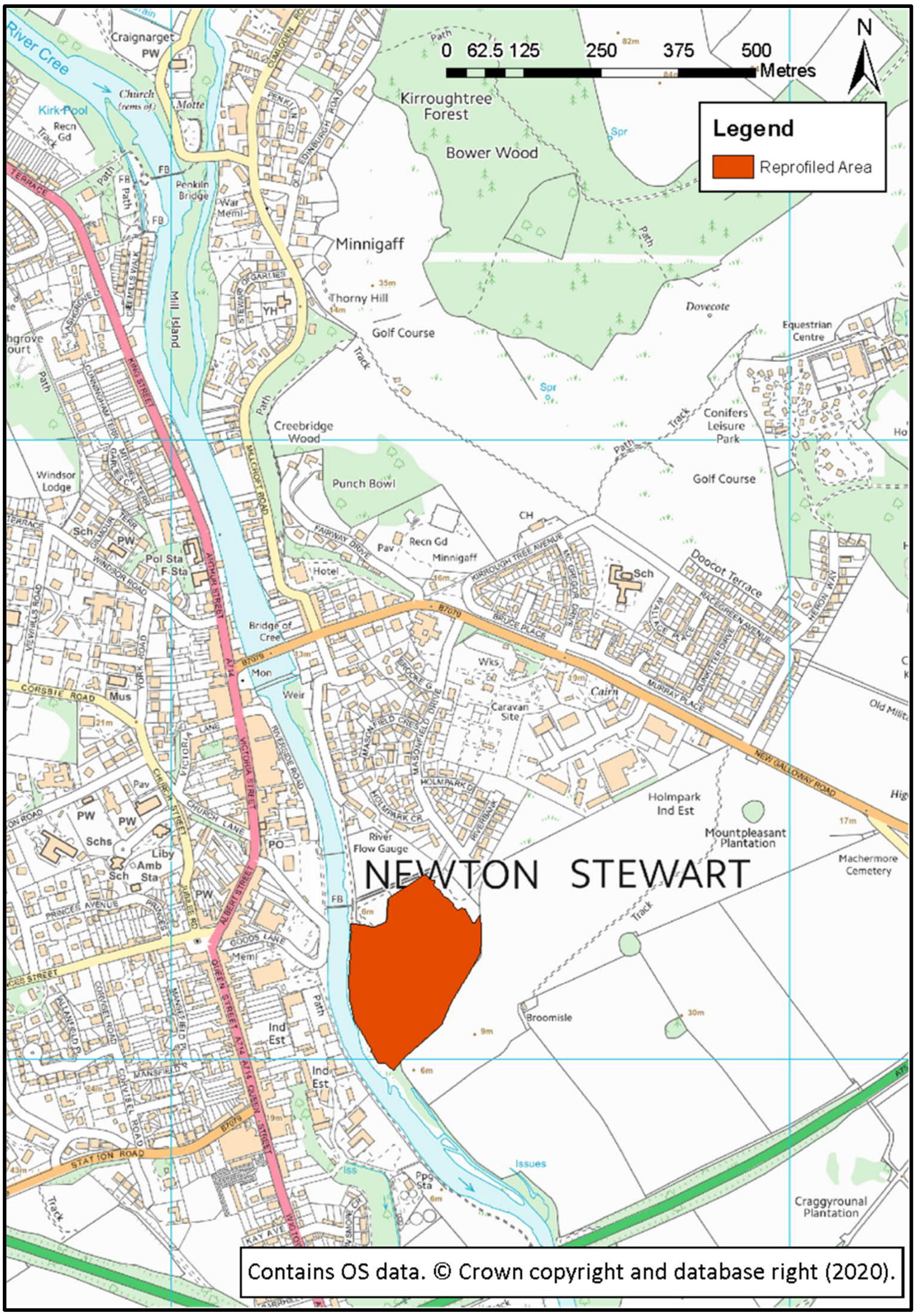

Figure 3-23 - Reprofile Land at Pumping Station - Area of Reprofiling

3.10.3 **Hydraulic Modelling Findings**

It was found that reprofiling of land in this area could potentially reduce the number of flooded receptors from 133 (at present) to 131. The 200-year return period event flood map is shown in Figure 3-24.

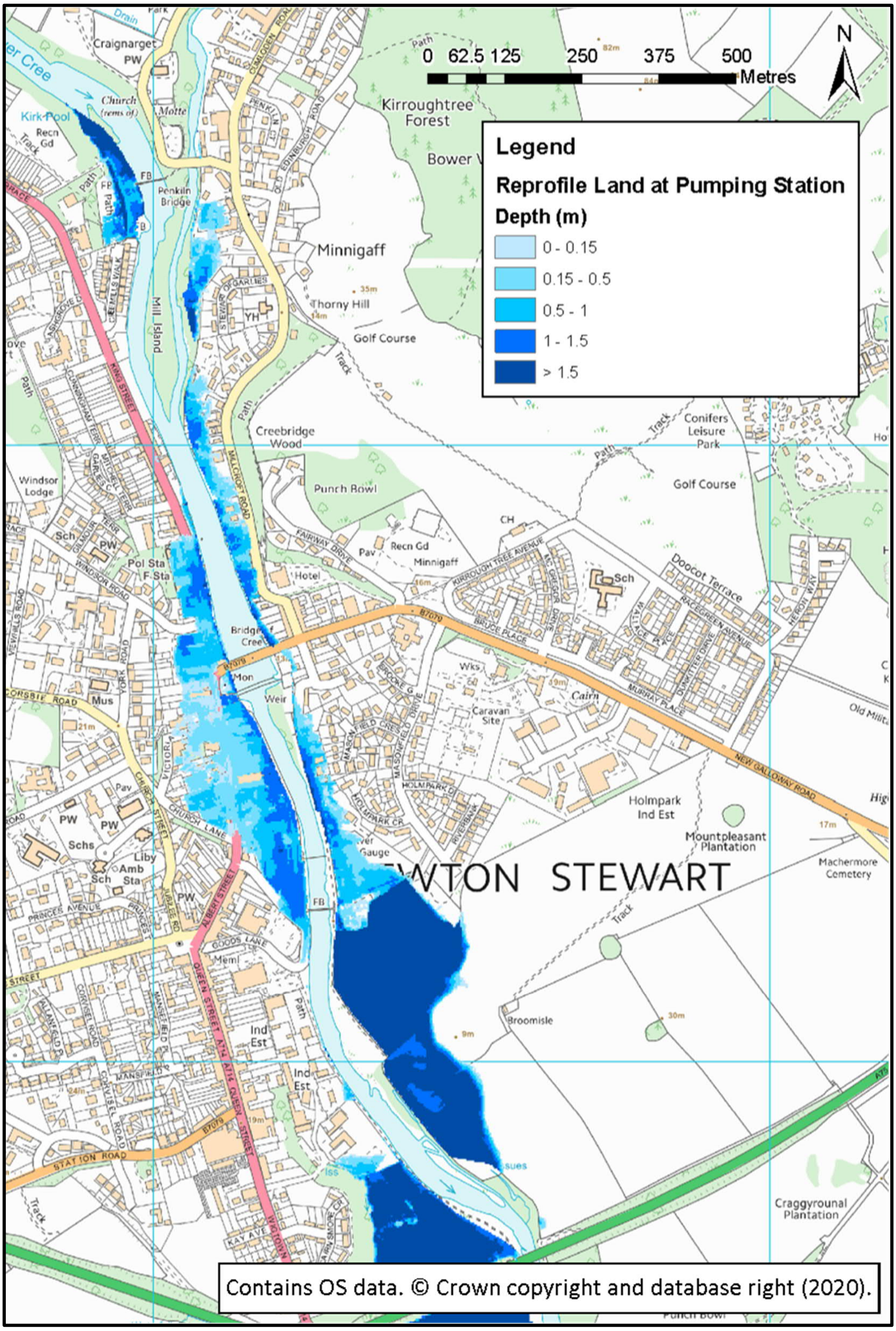

Figure 3-24 - Reprofile Land at Pumping Station - 1:200 Year Predicted Flood Outline

3.10.4 Geo-Environmental Findings

The main geo-environmental constraints identified for this option are presented in Table 3-11.

Table 3-11 - Reprofile Land at Pumping Station - Geo-Environmental Constraints

Constraint	Impact
Proximity to infilled quarries and gravel pits	**Low**
Proximity to former public slaughterhouse	**Low**
Protected species designations for freshwater fish	**Medium**
Potential for uncharacterised made ground	**Low**
Steep slopes	**Medium**
Uncertainty regarding foundation material for potential structures	**Low**
Potential for compressible materials to be present in situ	**Low**

3.10.5 Cost-Benefit Findings

The BCR for this option was found to be 1.48, showing a positive case for funding. While the number of receptors where flood risk is reduced is small, the impacts combined with this BCR show that the option was beneficial in conjunction with others.

3.10.6 Feedback from Stakeholders

CVCC referred to the presence of the pumping station on the floodplain and the original planning application for its construction. Discussion on this did not continue, as a past planning decision would not impact the flood scheme moving forward. CVCC expressed their support that the idea of returning some of the area to floodplain had been considered. They also raised the issue of the positioning of the new Sparling Bridge in a nearby location and the design team noted that this may be a constraint for some of the area.

3.10.7 Decision

It was decided to progress with a variation on this option. Option 7 (which was progressed) proposed a two-stage channel on approach to the A75T bridge. Given that the concept which was shown here was that some of the floodplain should be returned to the river near to the pumping station, and to ensure that visual impact of the scheme is minimised, it was decided to progress this option as an extension to the two-stage channel proposed as part of Option 7.

3.11 Option Combinations

The following outcomes were obtained for combinations of options.

3.11.1 Combination 1: Options 7 and 9

Modelling of this combination comprised increasing flow area beneath the A75T bridge and increasing the number and size of flood relief culverts beneath the A75T. This combination did not yield any reduction in receptors at the 1:200 year return period event, and gave a BCR of 0.32. This is greater than the BCR obtained for option 9 on its own.

3.11.2 Combination 2: Options 7 and 19

Modelling of this combination comprised increasing flow area beneath the A75T bridge and reprofiling land at Broomisle. This combination did not yield any reduction in receptors at the 1:200 year return period event, and gave a BCR of 1.10. This is greater than the BCR obtained for option 19 on its own.

3.11.3 Combination 3: Options 7 and 24

Modelling of this combination comprised the configuration of increasing flow area beneath the A75T bridge and reprofiling land around the pumping station. This combination reduced the number of flooded receptors by 2 at the 1:200 year return period event, and gave a BCR of 1.26. This is greater than the BCR obtained for option 24 on its own.

3.11.4 Combination 4: Options 7, 9 and 19

Modelling of this combination comprised the configuration of increasing flow area beneath the A75T bridge, increasing the number and size of flood relief culverts beneath the A75T and reprofiling of land at Broomisle. This combination did not yield any reduction in receptors at the 1:200 year return period event, and gave a BCR of 0.15. This is greater than the BCR obtained for option 19 on its own.

3.11.5 Combination 5: Options 9 and 19

Modelling of this combination comprised increasing the number and size of flood relief culverts beneath the A75T and reprofiling of land at Broomisle. This combination reduced the number of flooded receptors by 2 at the 1:200 year return period event, and gave a BCR of 0.26. This is greater than the BCR obtained for option 19 on its own.

3.11.6 Combination 6: Options 9 and 24

Modelling of this combination comprised increasing the number and size of flood relief culverts beneath the A75T and reprofiling of land around the pumping station. This combination did not yield any reduction in receptors at the 1:200 year return period event, and gave a BCR of 0.50. This is greater than the BCR obtained for option 9 on its own.

3.11.7 Combination 7: Options 19 and 24

Modelling of this combination comprised reprofiling of land at Broomisle and around the pumping station. This combination reduced the number of flooded receptors by 1 at the 1:200 year return period event, and gave a BCR of 0.42. This is greater than the BCR obtained for option 19 on its own.

3.11.8 Overall Findings & Stakeholder Response

The analysis of option combinations highlighted the positive additive effect of considering more than one single solution. This was shown through the increases in BCR brought where more than one option was modelled. Discussion at the VM2 meeting with stakeholders did not select any given combination of options from the above list, but did validate the decision to progress of a combination of three individual standalone options to be designed to work together.

3.12 VM2 Summary and Conclusions

Table 3-12 shows a summary table of the results presented throughout Chapter 3 for reference.

Table 3-12 - Summary of Findings – Short-list Options

Option	Description	Reduction in Receptors at 1:200 Year Event	BCR (Optimism Bias 60%)
2	Upstream Storage at Linloskin Bridge	0	N/A
4	Installation of Obstructions on the River Cree	0	N/A
6a	Direct Defences South-West	-11	0.62
6b	Direct Defences North-West	34	0.84
6c	Direct Defences West	106	1.24
6d	Direct Defences West & South-East	113	0.86
6e	Direct Defences All Areas	131	0.68
7	Increase Flow Area Beneath A75 Bridge	0	9.84
9a	Additional Flood Relief Culvert Beneath A75	0	0.31
9b	2x Additional Flood Relief Culverts Beneath A75	0	0.24
9c	Upsizing Flood Relief Culverts Beneath A75	0	0.14
19	Reprofile Land at Broomisle	0	0.09
20	Reinstate Storage Area at Water of Minnoch	0	N/A
21	Upstream Storage at The Ghyll	N/A	N/A
22	Upstream Storage in River Cree Tribuaties	0	N/A
24	Reprofile Land Around Pumping Station	2	1.48
C1	Options 7 & 9	0	0.32
C2	Options 7 & 19	1	1.10
C3	Options 7 & 24	2	1.26
C4	Options 7, 9 & 19	0	0.15
C5	Options 9 & 19	2	0.26
C6	Options 9 & 24	0	0.50
C7	Options 19 & 24	1	0.42

4 Preferred Options

At the VM2 meeting and subsequent consultations, the stakeholders agreed that the preferred option should, in addition to the relocation of the Sparling Bridge, be a combination of the following (as shown indicatively in Figure 4-1):

- Direct defences including flood gates(*option 6);*
- Reprofiling of land beneath A75T bridge (*option 7); and*
- Reprofiling of land around the pumping station (*option 24)*

Feedback on this preferred option has been sought at the public exhibition event held in June 2018 and subsequent consultations. Further details on the preferred option and outline design are provided in the Flood Management Preferred Option and Economic Appraisal report, also produced by Sweco. The preferred option for the scheme is illustrated on the following page:

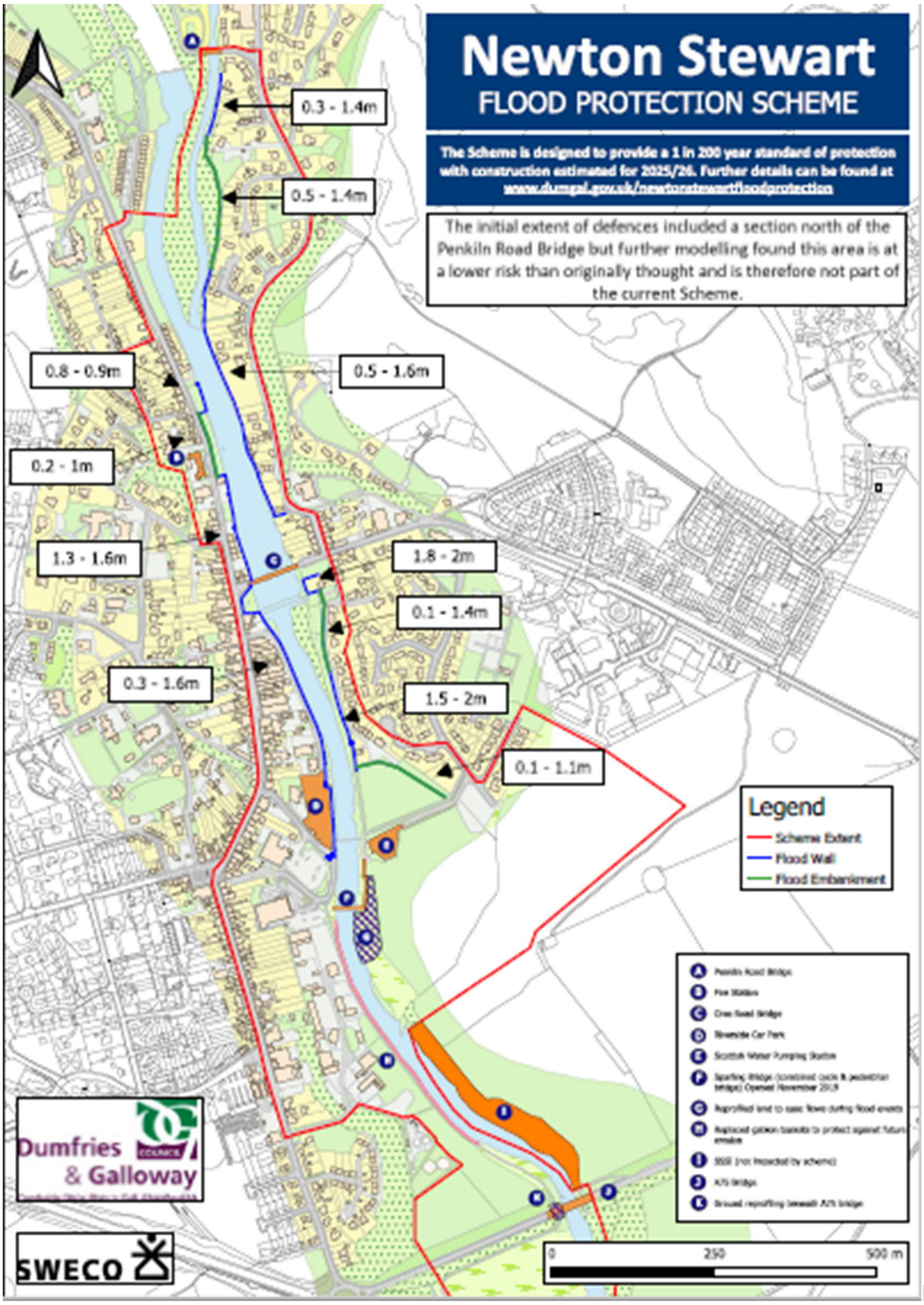

Figure 4-1 - Indicative Plan of Preferred Option