Grangemouth Flood Protection Scheme

Technical Note for Cell 2 - Dalgrain Road Area

B2386100-JEC-S4-C02-ZZZ-TN-C-0001| P03

December 1, 20201

Falkirk Council

B2386100

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Grangemouth Flood Protection Scheme

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Contents

1. Guidance to Readers

This Technical Note (TN) has been produced to assist and support the decision-making process during the Outline design of the Grangemouth Flood Protection Scheme (the Scheme). There are multiple TN's for the Scheme and each TN focuses on identifying a recommended design solution for one specific location or area.

TN's are produced where there may be multiple design options for a flood defence solution, each within their own positive and negative impacts in relation to parameters such as Time, Cost, Social or Environmental disturbance, and are a means, within the design process, to help assess and refine those options.

The TN's should not be considered as full option appraisals, or should they have to meet the formal requirements of that process as outlined in "Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities", published by the Scottish Government in 2016. The TN's have been developed by members of the Technical Workstream and drafted in an open and transparent manner, with the principal focus of the TN being technical aspects. The TN's have been drafted using experience and professional judgement gained from working on other flood protections schemes in Scotland. Within the TN's any comparative assessment in relation to parameters such as 'time' or 'cost', i.e. Low, Medium or High impacts, for any option, are relative comparisons measured only, unless specifically noted otherwise, against the alternative options contained within that specific TN.

The variation between a 'Low', 'Medium' or 'High' value is typically where the measure being compared is considered to have a difference in quantum which is judged to be significant enough to influence the decision-making process for the options being assessed within each individual TN. There are no overarching threshold trigger levels between these categories which extend to all TN's, and a high-level comparison of these categories between other TN's shouldn't be carried out, what is a high cost option in one TN could very well be a low cost compared to options being considered in another TN.

Each TN has included a 'light touch' Equality Poverty Impact Assessment (EPIA), which is specific to the TN. A full EPIA will be carried out at key project milestones and recorded within Falkirk Council's systems.

Each TN will review the options being considered against the twenty Design Principles which have been developed to record and justify how the flood defence alignment has been determined by the project team. Not all the design principles will be applicable to all the options considered in the TN's, professional judgement will be used to determine which principles should be scoped out.

The recommended option identified for each TN, should be seen as an interim recommendation that will be subject to change once the 'next steps' are completed. Additional checks and reviews will also be undertaken as the outline design process is concluded prior to developing the scheme documents. It should also be noted that once any 'next steps' identified are carried out the TN will be subject to a further review to confirm the continued suitability of the recommended option or otherwise.

2. Introduction

The purpose of this technical note is to outline the options and construction methods for providing flood defences along a 750m length of the River Carron, from the Jarvie Plant yard on Dalgrain Road, to the Leisure Harbour which is occupied by several businesses. The flood defences will provide a 1 in 200-year standard of protection.

The objectives of this technical note are:

- to outline flood defence alignment options;
- to outline methods of construction;
- to provide outline cost estimates for flood defence options;
- to comment on environmental and social impacts of the options;
- identify areas requiring further investigations/considerations;
- to identify an option which should be incorporated into the published scheme.

2.1 Site Description

Error! Reference source not found. shows the site, located to the east of Glensburgh. There are four commercial business premises that occupy a strip of land between Dalgrain Road/Forth-Clyde Way and the River Carron. Three of the commercial premises Scotty's Garage, Jarvie Plant and CCS Scaffolding all require access off Middle Street Lane. Rossco Properties requires access off Grange Lane. The River Carron bounds all four premises to the north.

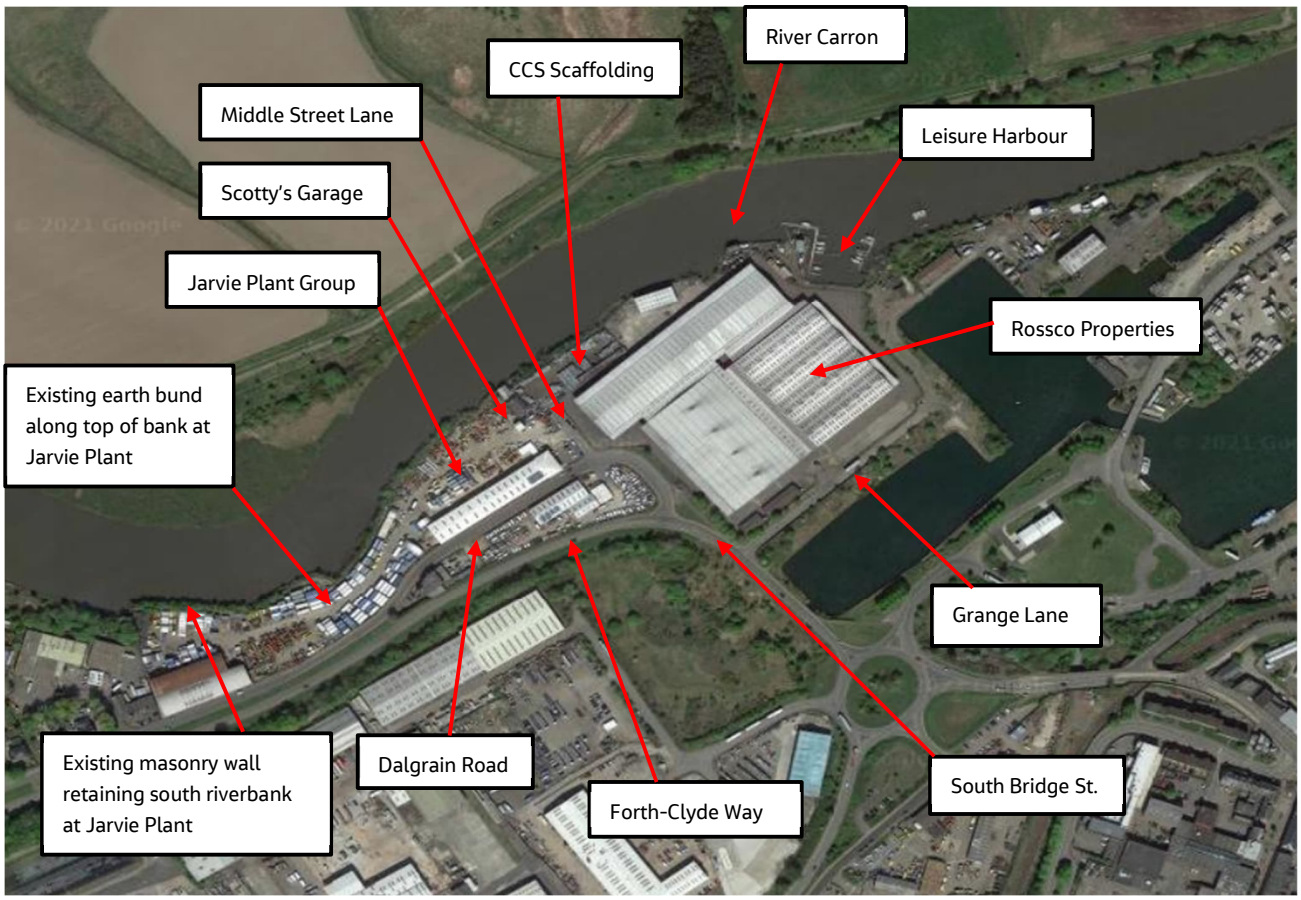

Figure 1 Location Plan

2.1.1 Existing Bank / Masonry Wall

The section of riverbank discussed in this technical note is ~750m in length and extends from the west end of the Jarvie Plant yard to the Leisure Harbour, next to the Rossco Properties site. The bank is retained in sections by an existing masonry wall and an earth bund has been constructed along the top of the bank at the rear of the Jarvie Plant yard. There are remnants of an old timber wharf structure along the toe of the bank, that appear to be in a very poor condition. Most of the bank is heavily vegetated in this area.

To the west of the Jarvie Plant yard, a ~2.5m high (full height of the bank) masonry wall retains a ~165m long section of riverbank. The wall appears to be in a fair/poor condition with missing mortar between the blocks. A partial collapse of the wall has occurred towards the east end of the Jarvie Plant yard. Timber piles (remnants of wharf structure) appear to offer some support to the wall/riverbank, but the timber is showing signs of decay and in places the structure has collapsed.

2.1.2 Existing Earth Bund

An earth bund has been formed on top of the existing riverbank as an informal flood defence. The bund appears to be constructed from random materials, which are loose, potentially unstable and may contain contaminates, (linked to the areas historical land use). The bund will not form part of the future flood protection scheme structure and will not be included in the flood model due to its poor condition and random construction material.

2.1.3 Historic Land Use

This section of riverbank has a history of heavy industrial use, with records showing the site has been occupied from 1864 to present by a variety of industries such as gas works, metal works, ship building, timber works, scrap yard and warehouses.

From ground investigation work carried out in 2019, significant areas of contamination have been identified. Asbestos has been found consistently though-out the site at varying depths (0.2m – 0.5m) at levels above the human guideline value of 0.001%. Hydrocarbons were encountered in ground water at shallow depths; however, groundwater monitoring did not reveal contamination from deeper groundwater. Significant quantities of Total Petroleum Hydrocarbons (TPH) were found in the soil at several locations. Lead was also encountered at varying depths across the site.

2.2 Options

The following options to be considered are:

- **Option 'A'** - Flood embankment along top of existing bank, protecting all premises
- **Option 'B'** - Floodwall along top of existing bank, protecting all premises
- **Option 'C'** - Floodwall set-back from existing bank, protecting all premises
- **Option 'D'** - Floodwall along Dalgrain Road, not protecting four commercial premises
- **Option 'E'** - Floodwall along Forth-Clyde way, not protecting four commercial premises

2.3 Potential Ground Contamination

As outlined in section 2.1.3, the historical land use of the site and ground investigation work undertaken to date has identified the potential for Jarvie Plant site as having contaminated ground including asbestos. Consideration of this will be required when appraising the options within this technical note to ensure Falkirk Council are compliant with current health and safety and environmental legislation regarding contamination and hazardous wastes. Options should consider the exposure and disturbance risks during construction of the flood defences as well as the risks once the scheme is operational including the potential for contaminants to be disturbed by a flood event.

3. Flood Risk

3.1 Baseline Water Levels

Flood water levels on this section of the River Carron (Lower Carron) are heavily influenced by the tides from the Firth of Forth. The onset of flooding in this area is around the 1 in 5-year (baseline event), where overland flow spreads out across low lying ground from the southwest, with the Jarvie Plant site underwater by up to ~0.177m depth, though most of the flooded area (red on the plan below) would be up to 0.07m under water. The bund on top of the existing bank has not been included in the model, as the bund is not deemed to be a formal flood defence. This does impact the flood extents in Figure 2, which indicate flooding in the Jarvie Plant site for a 5-year event may be slightly conservative if the bund offers some protection from flooding, but we are not able to quantify this and do not have confidence in the integrity of the bund, therefore the bund has not been modelled this area.

An area to the northeast corner of the Rossco Properties site also has some localised flooding from a 5-year event, but this is isolated in a small low-lying area of ground. The main onset of flooding for Rossco Properties and Scotty's Garage/CCS scaffolding is from around the 1 in10-year. The variance between the 10-year water levels at Rossco Properties and Scotty's Garage is a result of local topography and the 2D water levels which allows water to pond in low lying areas, even though the top of bank level may not have been exceeded.

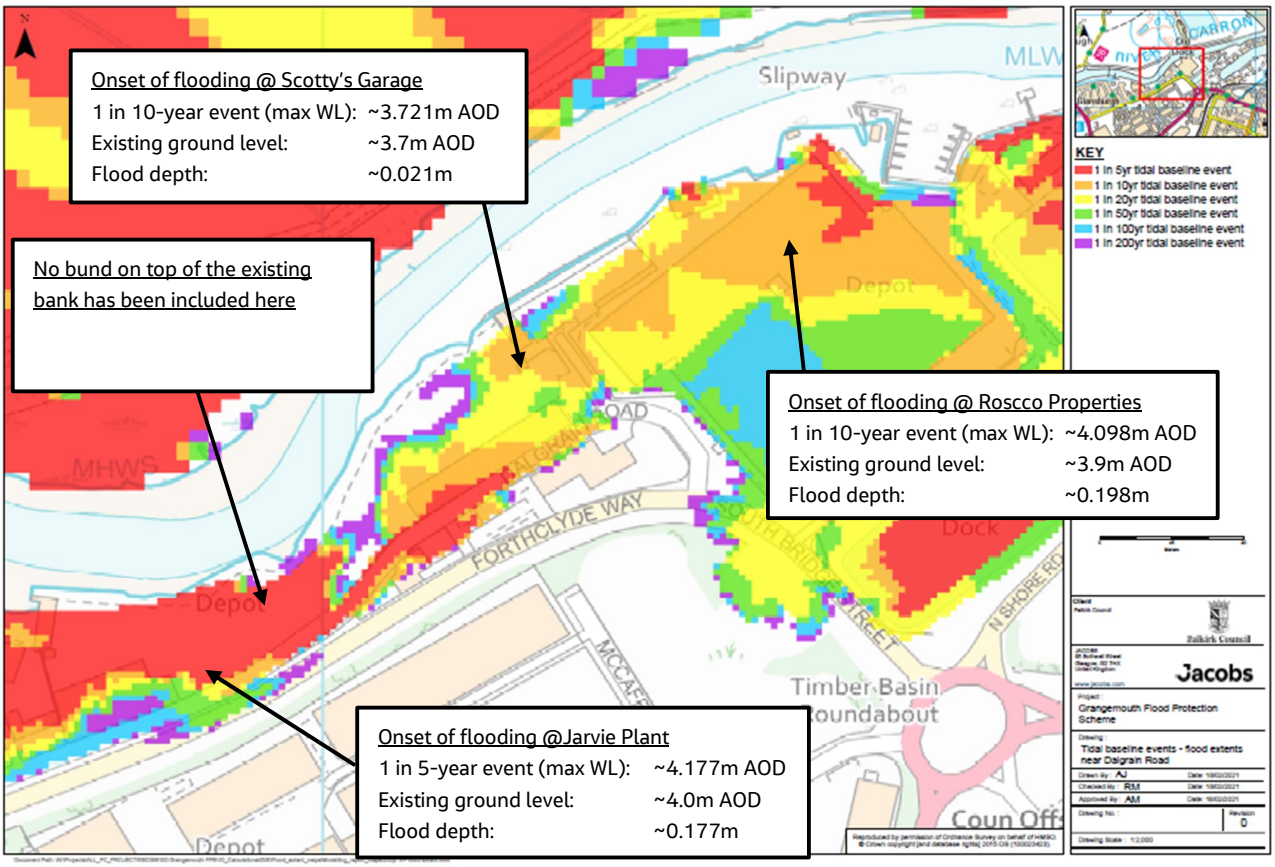

Figure 2 Extent of Flooding from Baseline Events

Error! Reference source not found. shows the extent of flooding from the baseline 200-year event. Most of the Jarvie Plant site would be underwater, up to ~0.5m depth. Some of the storage buildings at the western end of the yard, would have flood water in them up to a depth of ~0.7m. The office building situated at the southeast corner of the site would have flood water in it up to ~0.34m. Scotty's Garage and the CCS scaffold yard would be underwater up to 0.54m depth. At Rossco properties the main depot building would have flood water in it up to ~0.79m depth.

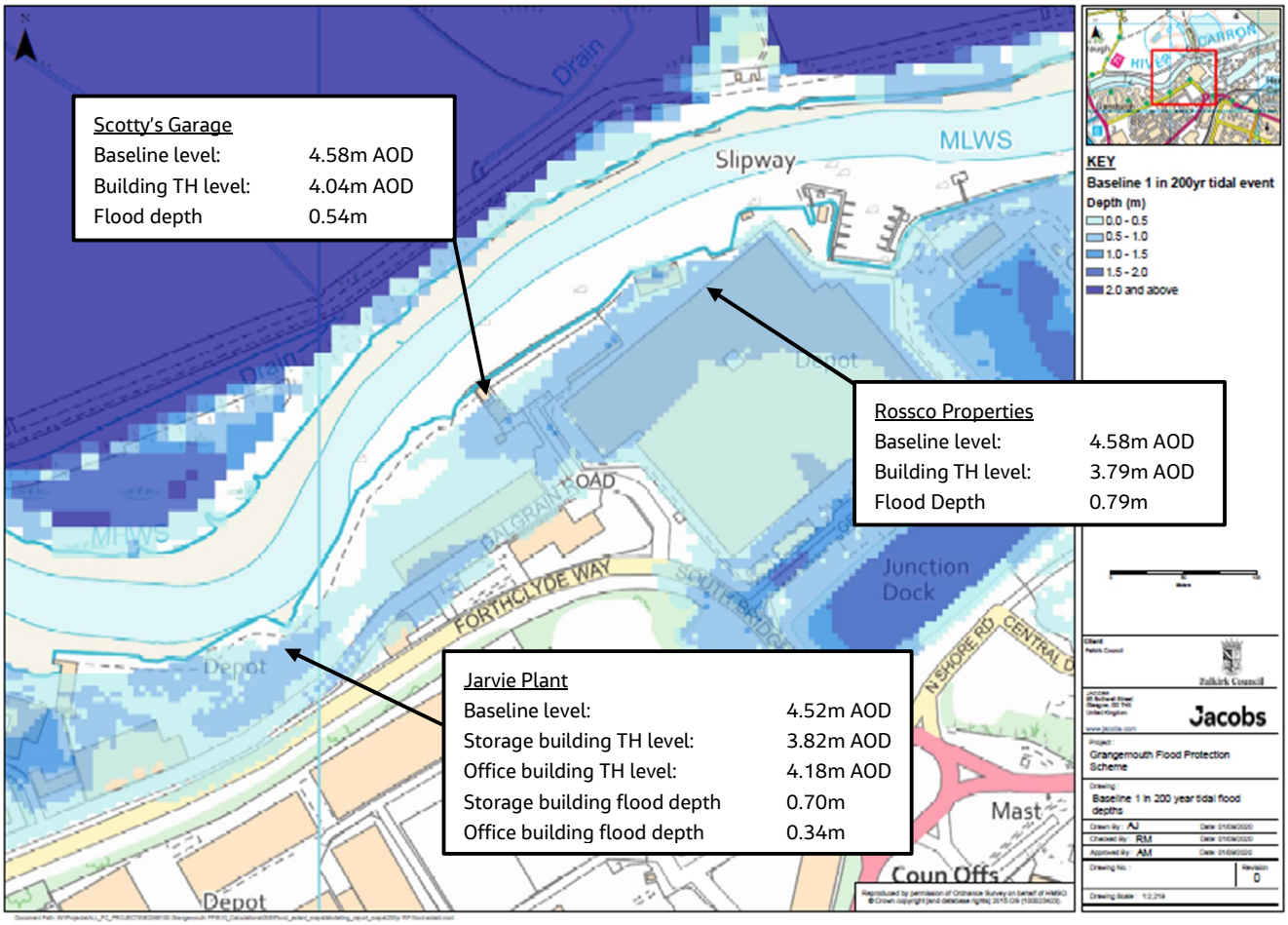

Figure 3 – Extent of flooding from Baseline 200-year event

3.2 Post Scheme Water Levels

3.2.1 Options A, B and C

The post-scheme water levels on the wet side of the flood defences for options A, B and C are the same as the baseline.

Further analysis has been carried out to determine flood risk associated with options D and E, as these options involve constructing flood defences further inland.

3.2.2 Option D – Alignment along Dalgrain Road

Generally, there is a decrease in the depth of flood water, there is a small area where the depth of flood water increases by up to ~0.3m in a localised area in the southwest corner of Jarvie Plant's yard. This is due to flood defences being set-back from bank and a localised low point at ~3.70-m AOD. To allow for construction of flood defences the existing building in this area would be demolished, ground levels here could be raised locally to avoid the increase in water depth. Overall water levels decrease across the site by up to ~0.3m. This is due to the change in flow paths, with water directed towards flood plain on the north side of the river channel (refer **Error! Reference source not found.**).

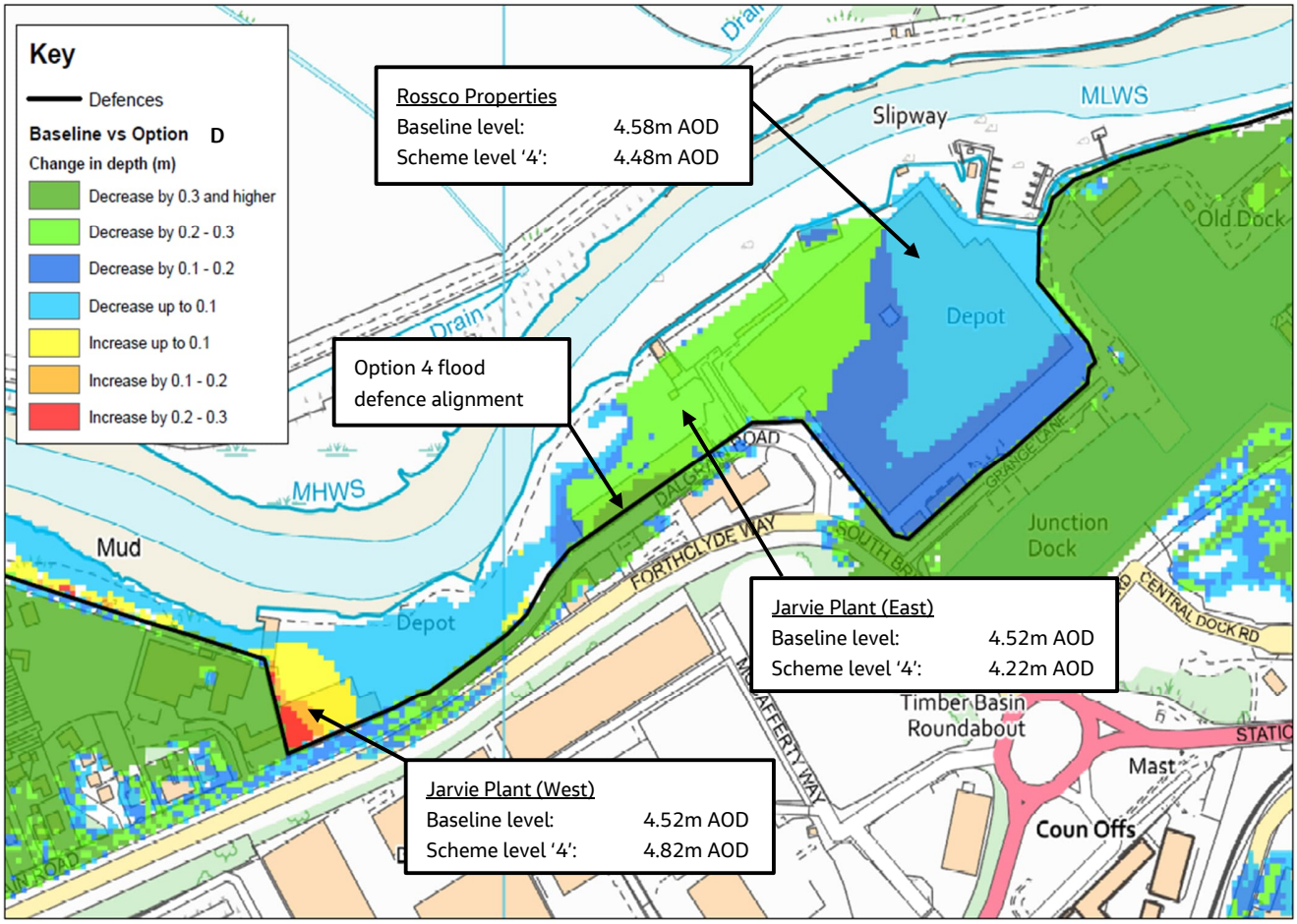

Figure 4, 200-Year Baseline Flood Extent/Depth v Scheme Option 4

3.2.3 Option E – Alignment along Forth-Clyde Way

Flood defences constructed along Forth-Clyde Way would have a similar impact on water levels to Option 'D'. An increase in water level up to ~0.3m (total ~1.0m depth) to the Southwest of the Jarvie Plant site where there is low ground levels, with a general reduction in water levels throughout the sites. Some minor re-profiling of the yard levels in this area could be undertaken to reduce any increase in water depth.

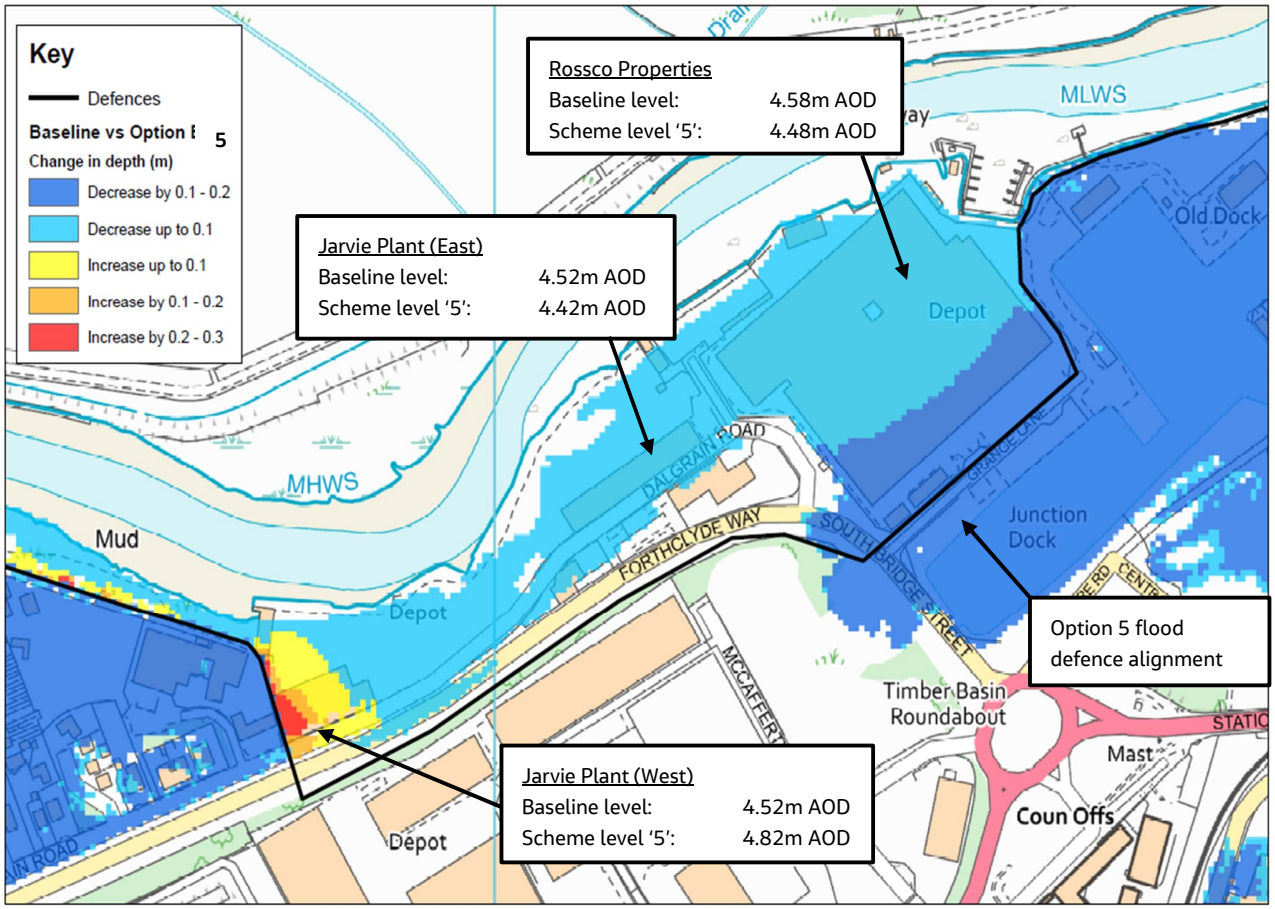

Figure 5 200-Year Baseline Flood Extent/Depth v Scheme Option 5

4. Existing Riverbank

4.1 Location at Jarvie Plant

Figure 6 outlines the critical geometry of the existing riverbank.

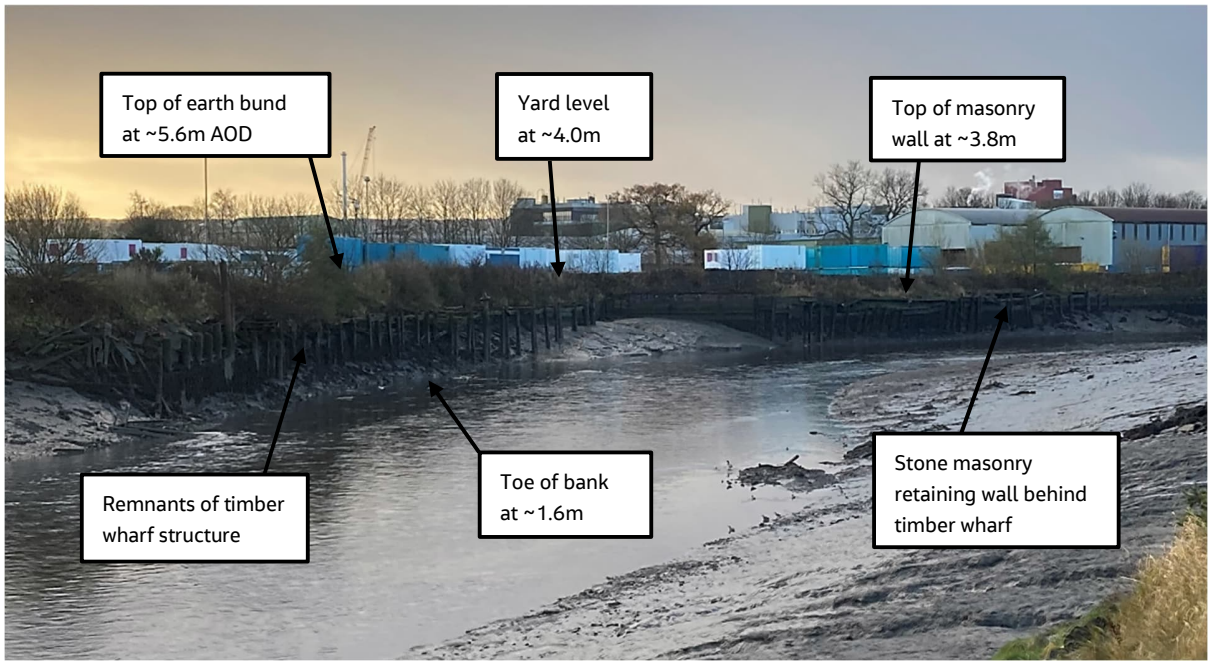

Figure 6 – Lower Carron, South bank at Jarvie Plant

The existing riverbank from the west of the Jarvie Plant yard is retained by a ~2.5m high stone masonry wall that extends ~165m downstream. The wall transitions to a steep earth bank that extends a further ~200m downstream towards the site occupied by Rossco Properties.

4.1.1 Timber Wharf

The remnants of a timber wharf structure can be seen at the toe of the bank; a dilapidated timber structure consisting of vertical timber piles and horizontal timber planks. From visual inspection it appears the remaining timbers may be providing some additional support to the riverbank, further investigation would be required to understand the overall stability of the existing bank, masonry wall and timber structure. This is not being carried out as part of this technical note.

4.1.2 Existing Bund

The existing bank level has been raised by an earth bund several metres in height. The earth bund appears to be an informal flood defence and extends along the length of the Jarvie Plant yard only. It is likely that the bund material has been placed loose and not properly compacted in layers, with material potentially containing contaminants, although the bund is heavily vegetated in sections which may be helping with its overall stability.

4.2 Location at Scotty's Garage / CCS Scaffolding

Figure 7 outlines key features on the riverbank.

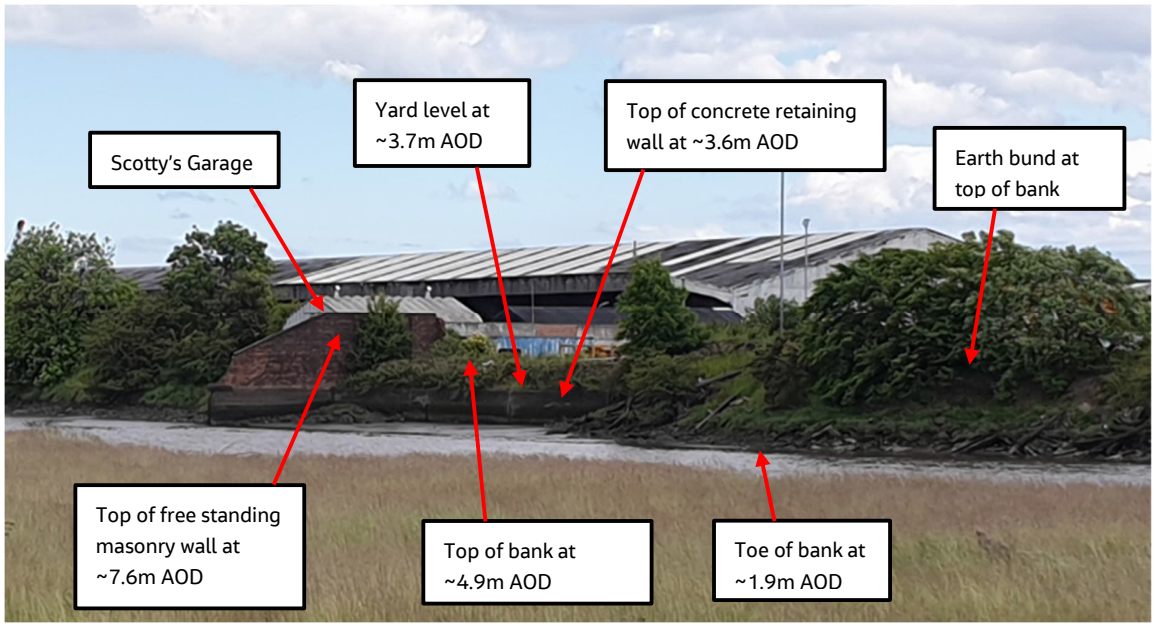

Figure 7 – Lower Carron, South bank at Scotty's Garage

The riverbank downstream from Jarvie Plant is graded at an approximate 1 in 2 slope and is heavily vegetated with trees and shrubs. An earth bund, formed along the top of bank ties into high ground, interfacing with a ~2m high concrete retaining wall that is supporting a localised section of riverbank. To the rear of Scotty's garage, a ~4m high free-standing brick wall, is off-set from the concrete retaining wall. The free-standing brick wall appears to serve no purpose to Scotty's Garage or the concrete retaining wall, it is likely the wall formed part of a historic building.

4.3 Location at Rossco Properties

Figure 8 outlines the key ground levels at Rossco Properties.

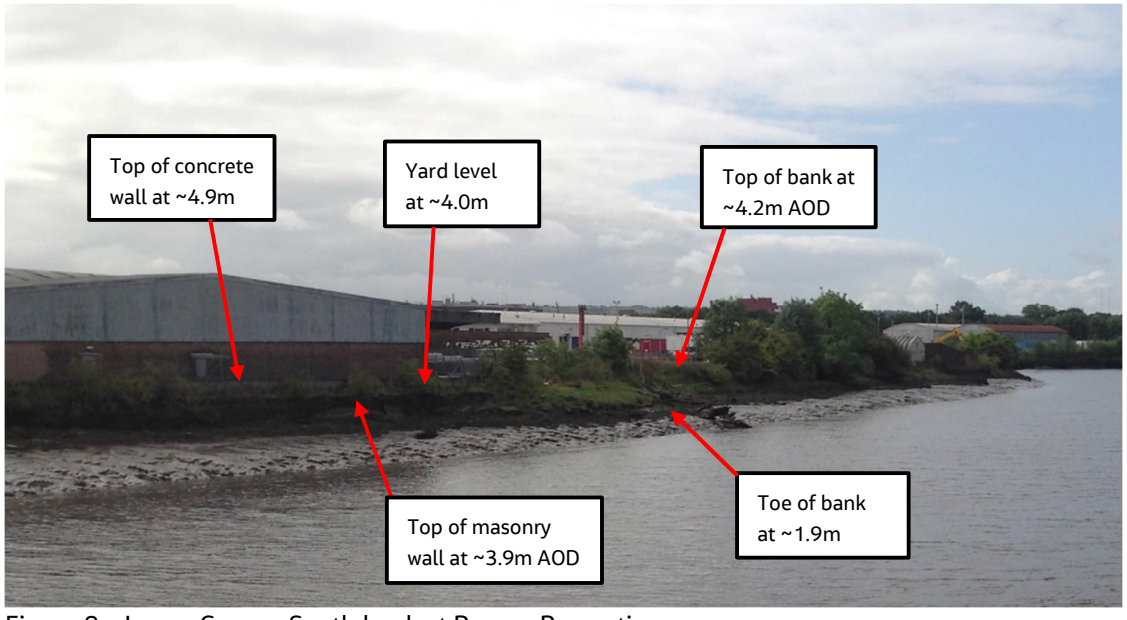

Figure 8 – Lower Carron, South bank at Rossco Properties

Along the perimeter of the Rossco properties yard, a concrete wall ~0.9m high has been constructed. The top of wall is at ~4.9m AOD which is 0.3m below the proposed flood defence level (5.2m AOD). The concrete wall has been constructed behind an existing stone masonry wall that retains the riverbank. From a visual inspection this wall appears to be in a poor condition, with a partial localised collapse. To avoid potential issues relating to liabilities, design life and condition of the existing wall, the existing masonry wall will not form part of the flood defence for the scheme.

5. Flood Defence Options

The following section outlines the options for flood defences and will:

- define the alignment,
- method of construction,
- identify constraints,
- identify utility diversion works, and
- outline cost estimate

The flood defences will be constructed to 5.20m AOD (200-year scheme + 0.6m freeboard) and will be designed to allow them to be increased (up to 0.7m) in height in the future. The proposed height of flood defences in this area are generally ~1.2m above existing ground levels.

Ground investigation works carried out, identify that made ground up to 5.0m depth covers most of the site. Below the made ground, cohesive marine deposits comprising of very soft to firm laminated silty clays range from 3m to 40m below ground level. This is underlain by cohesive glacial deposits comprising of soft to very stiff sandy gravelly clays up to 61m below ground level. Seepage analysis has not been carried out, but seepage is likely to be an issue where made ground is found up at to ~5m depth. Below made ground the underlying cohesive marine deposits are of low permeability and seepage would likely not be an issue.

5.1 Option A – Flood embankment along top of bank

5.1.1 Description of Option A

Construction of a flood embankment along this section of the River Carron is likely to require temporary works within the river channel, significant quantities of waste and potentially contaminated material being removed from site increases the risk of operatives being exposure to contaminants and there is potential for long-term settlement of an earth embankment on soft soils.

The existing stone masonry retaining wall along the western section of the Jarvie Plant yard, the dilapidated timber wharf and the existing earth bund along the riverbank would be removed. The riverbank would be re-profiled with suitable (compacted) material and keyed into the existing bank. The toe of the new embankment slope would need to be supported, this could be done by constructing a steel sheet pile structure or a rock armour revetment to ensure overall stability.

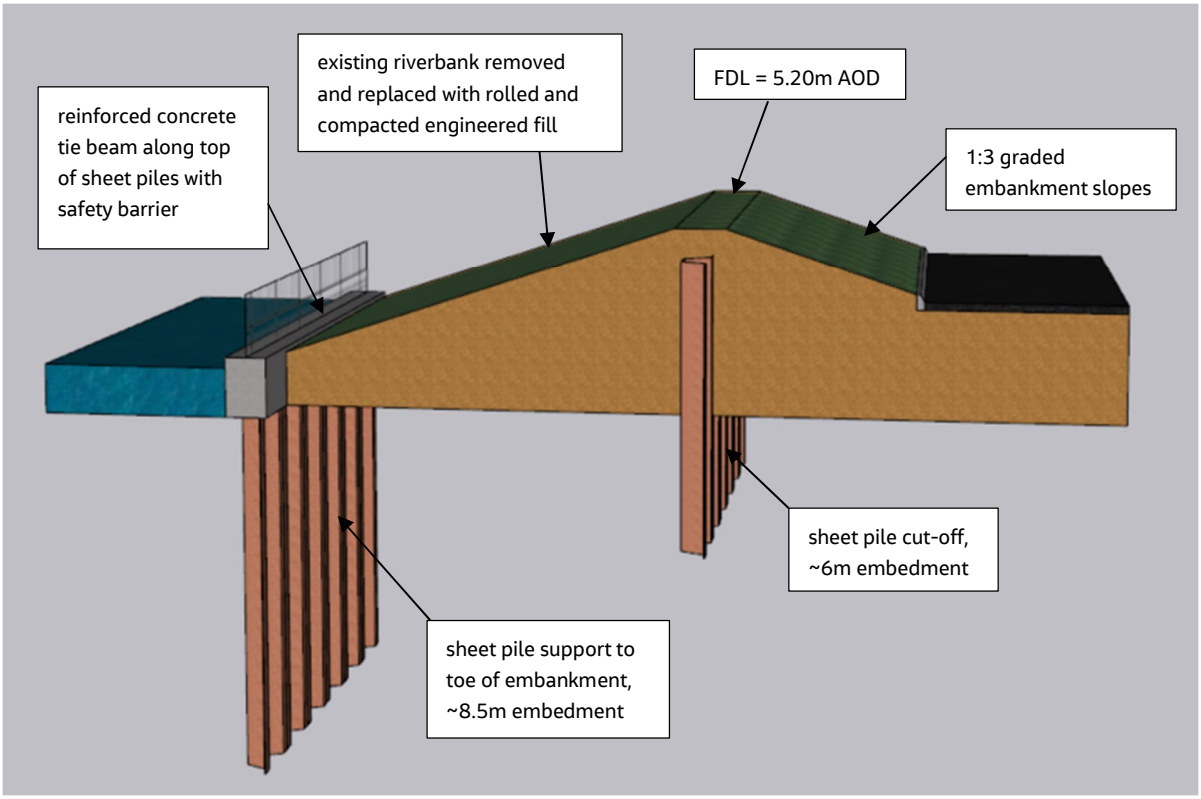

Figure 9 – Option A, flood embankment

5.1.2 Construction Footprint

The existing riverbank would be excavated back within Jarvie Plant's yard to achieve a design slope of 1 in 3. An embankment structure at this location would require a permanent footprint of ~15m wide, occupying a significant part of the existing yard space at Jarvie Plant.

The flood embankment footprint would occupy yard space at Rossco Properties and CCS Scaffolding. Scotty's Garage and one of the Rossco Properties buildings would need to be demolished. The existing concrete retaining wall would be removed, and the bank profile regraded or temporarily supported during removal of the retaining wall. A temporary working platform within the river channel may be required due to limited space to the rear of the property.

5.1.3 Utilities

Current records show a dual surface water sewer running west to east through the Jarvie Plant site, parallel to the riverbank. The sewer appears to be located ~20m inland from the riverbank and would likely be out-with the construction footprint, therefore no sewer diversion would be required.

Sewer pipelines that outfall into the River Carron cross the proposed flood alignment at several locations and would need to be retained (protected) and a new head wall structure installed with non-return / flap valve.

5.1.4 Contaminated Ground Risk

Significant excavation of the existing bank is required to allow the piled wall at the toe of the existing bank to be installed with the bank removed and reprofiled with imported fill. This option would require a significant volume of the existing bank (potentially contaminated ground) to be excavated.

5.2 Option B – Floodwall along top of bank

5.2.1 Description of Option B

The floodwall would be constructed to ~1.2m height above ground level (inside Jarvie Plant's yard). Construction of a floodwall along the top of the existing bank would involve removing the earth bund that extends ~300m along the perimeter of the yard. Slope stabilisation work is likely to be required, due to the proximity of the proposed floodwall to the top of the existing bank.

5.2.2 Option B1 - Steel Sheet Pile Wall

Sheet piles would be driven to an embedment depth of ~8.5m. There would be a reliance on the ground in front of the wall to provide passive resistance, if this is not the case, further reinforcement of the existing bank would be required.

Reinforcing a sheet pile structure to retain the bank would be difficult to achieve in such weak soil conditions. Therefore, to utilise the existing riverbank as part of the design solution, the existing bank would need to be stabilised and protected from erosion, possibly in the form of a rock armour revetment. This is likely to require work from within the river channel.

The wall could be constructed as a bare steel sheet pile wall above ground level or have a cast in-situ reinforced concrete stem that could be clad in masonry or have a cast pattern profile finish.

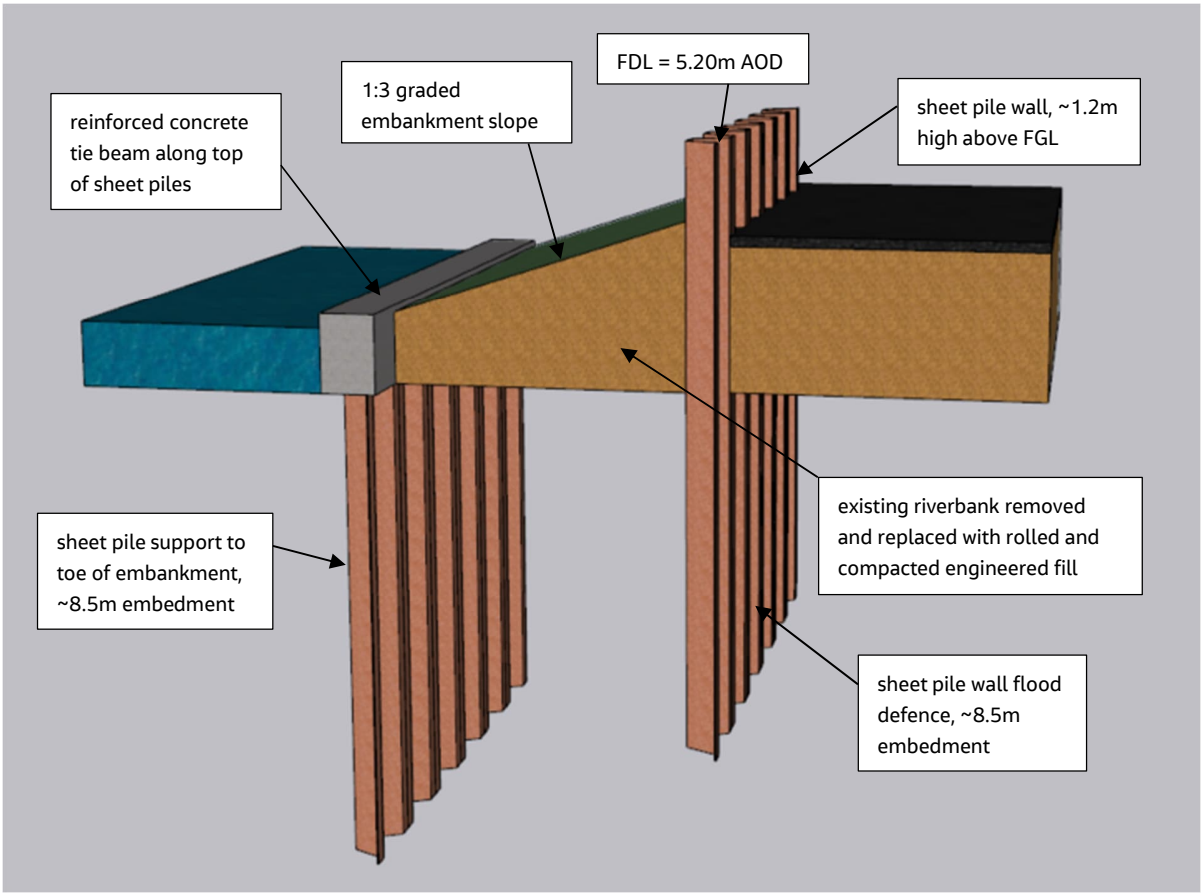

Figure 10 – Option B1, bare sheet pile flood wall and bank stabilisation

5.2.3 Option B2 - Reinforced Concrete Cantilever Wall

Constructing a traditional reinforced concrete cantilever wall along the top of the existing bank would require stabilisation work to be carried out to the riverbank. To reduce the construction footprint and depth of excavation the ground in front of the wall would be relied upon for overall global stability of the structure.

The wall would be founded within made ground to a depth of ~1m. It is anticipated that made ground is up to ~5m deep at this location, so seepage below the wall would likely be an issue. A seepage barrier would be required.

It would be possible to mitigate the need for a seepage barrier by founding the wall on the underlying cohesive strata, but this would require significant excavation to a depth of at least ~5m. Founding the wall directly on this material would inevitably lead to settlement issues. Ground improvement methods would likely be required to increase strength of the existing ground or alternatively a piled foundation solution could be adopted.

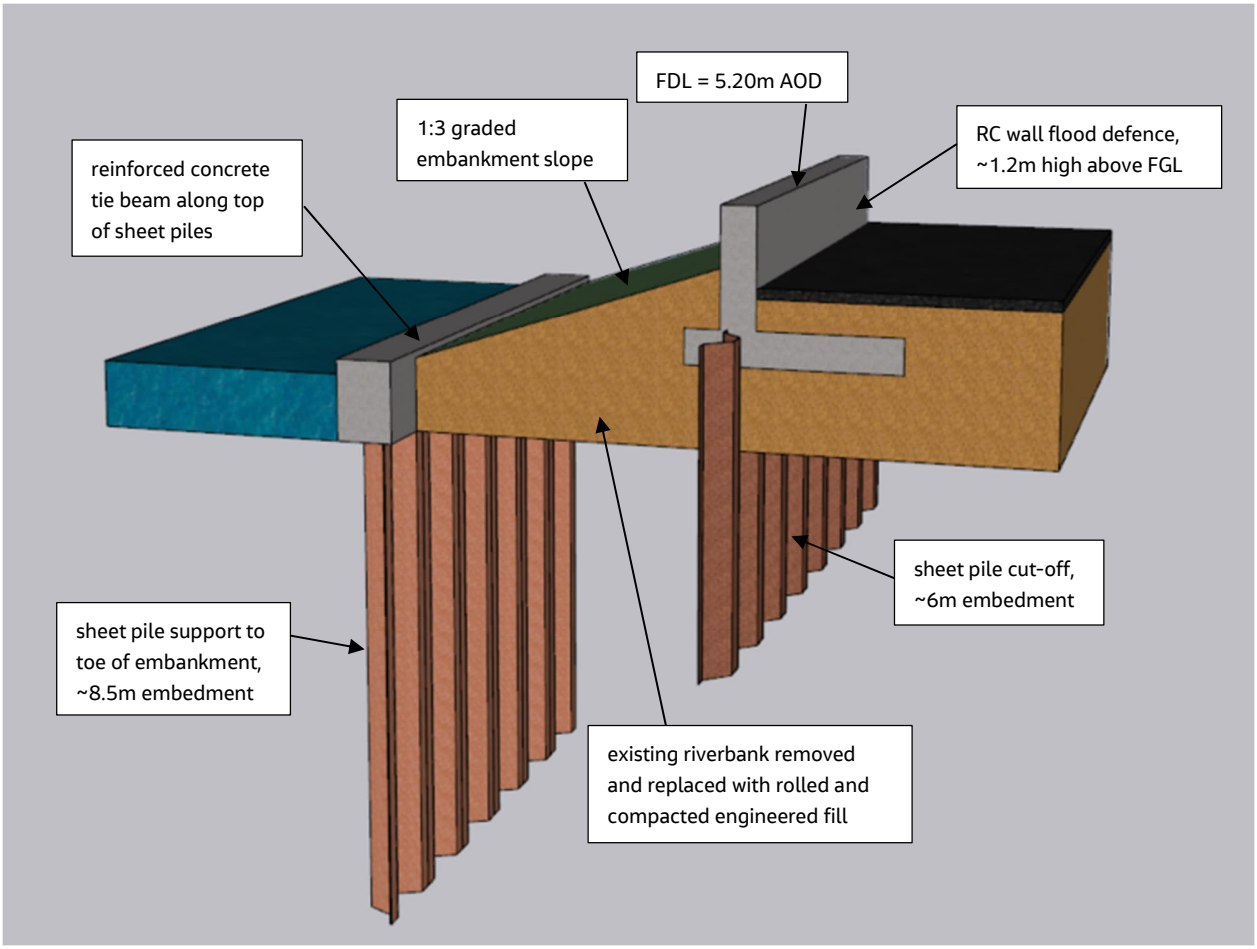

Figure 11 – Option B2, RC cantilever flood wall with seepage cut-off and bank stabilisation

5.2.4 Existing Bank Stability

Preliminary slope stability analysis of the existing riverbank was carried out to determine the extent of slope failure. It is assumed that if a rotational slope failure were to occur it would extend a linear distance of ~8m inland from the river-side toe of existing bank.

As stated in Section 2.1.2, the earth bund along top of bank is not a formal flood defence. From visual inspection the material appears not to of been compacted, although it is heavily vegetated which may aid stability. The dilapidated timber wharf structure may be offering some support to the toe of the existing bank.

5.2.5 Utilities

As per Section 5.1.3, no utilities run parallel within the construction footprint, there are several crossing points where surface water outlet tails discharge into the River Carron, these would be integrated into the flood embankment structure with new head walls installed.

5.2.6 Contaminated Ground Risk

Significant excavation of the existing bank is required to allow the piled wall at the toe of the existing bank to be installed with the bank removed and reprofiled with imported fill. This option would require a significant volume of the existing bank (potentially contaminated ground) to be excavated.

5.3 Option C – Floodwall setback from top of bank

5.3.1 Description of Option C

Aligning the flood wall back from the toe of the existing riverbank; out-with the slope failure zone / envelope of the existing bank, mitigates this risk. This option avoids the need to carry out stabilisation work on the existing bank which may have required work from within the river channel.

Additionally, this option offers the potential to extend the existing Charlotte Dundas footpath along the riverbank on the wet side of the wall and could link provide access to the Leisure Harbour or Dalgrain Road.

5.3.2 Option C1 – Steel sheet pile wall

From preliminary slope stability analysis, the sheet pile wall would be setback ~5m from the dry-side toe of the existing earth bund, a ~10m temporary construction zone would also be required. Aligning the sheet pile wall back from the existing earth bund, means the flood wall is out-with the slope failure zone / envelope for the existing bank. The permanent footprint would occupy ~15% of the existing yard space at Jarvie Plant, however, some land may still be useable on the wet side of the flood wall.

The floodwall would be constructed to ~1.2m height above existing ground level with steel sheet piles driven to an embedment depth of ~8.5m. The wall could be constructed as a bare steel sheet pile wall above ground or have a cast in-situ reinforced concrete stem that could be clad in masonry or have a cast pattern profile finish.

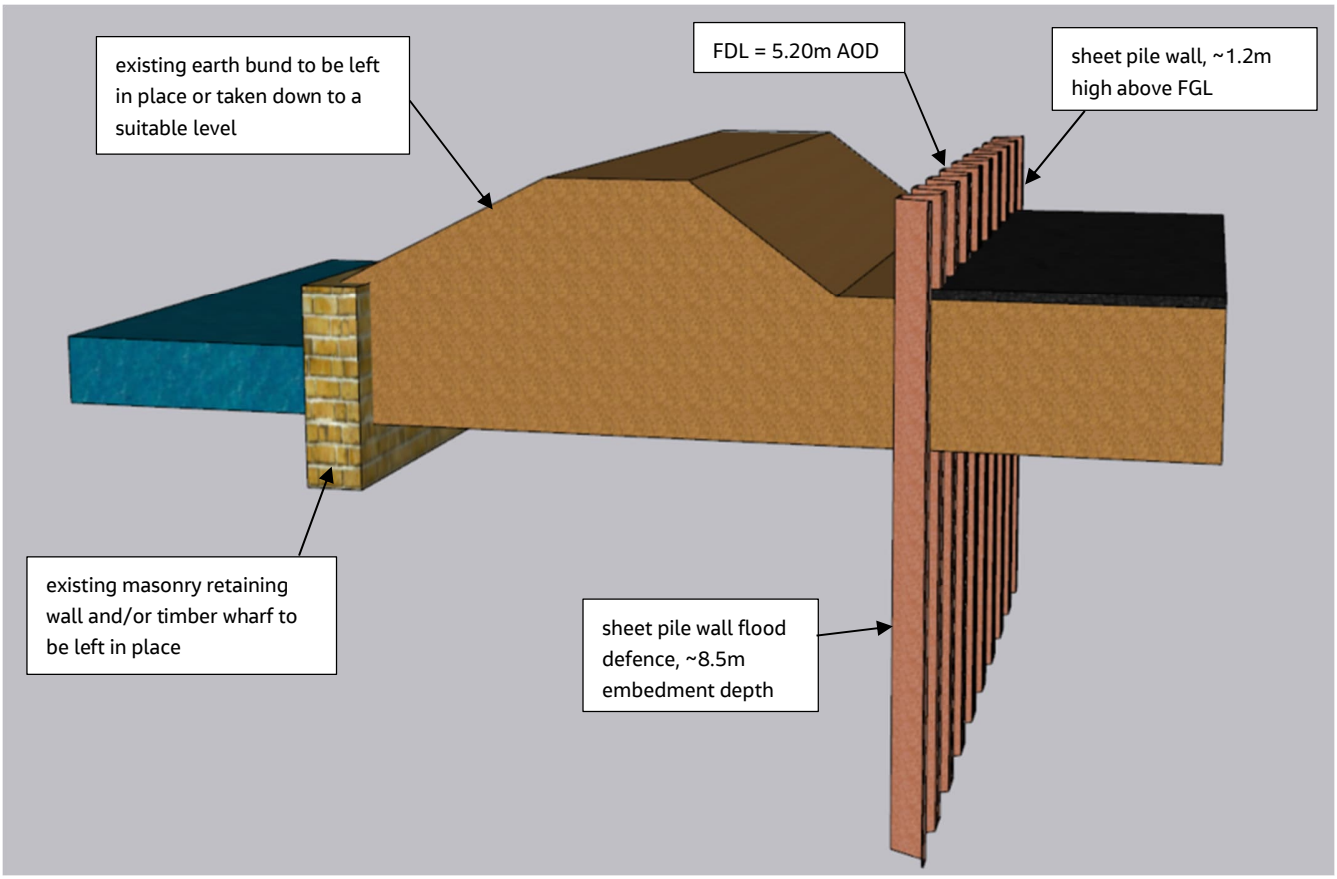

Figure 12 – Option C1, bare sheet pile flood wall

5.3.3 Option C2 – Reinforced concrete cantilever wall

A reinforced concrete cantilever wall would be located ~5m back from the dry-side toe of the existing earth bund a ~15m temporary construction zone would also be required. The permanent footprint would occupy ~15% of the existing yard space at Jarvie Plant.

The wall would be founded within made ground to a depth of ~1m. It is anticipated that made ground is ~5m deep within the Jarvie Plant yard. The embedment depth of the piles (8.5m) will also act as a seepage barrier..

It would be possible to mitigate the need for a seepage barrier by founding the wall on the underlying cohesive strata, but this would require deeper excavations ~5m. Founding the wall directly on this material could lead to settlement issues and, ground improvement measures are likely to be required.

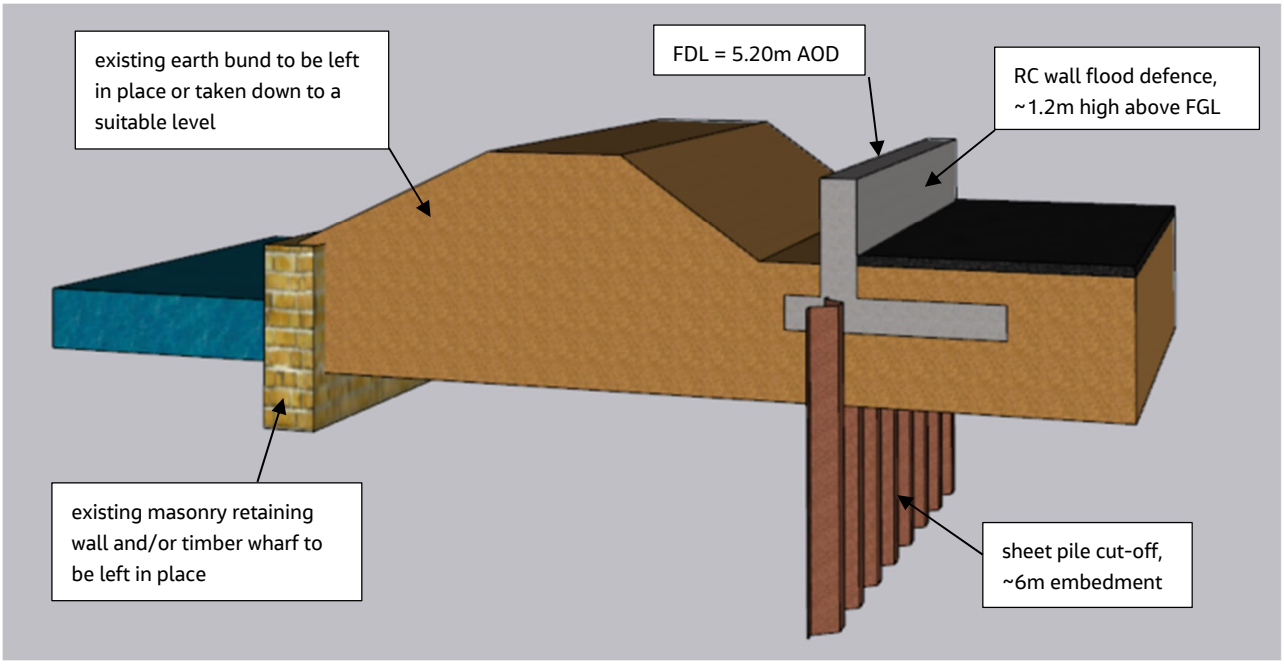

Figure 13 – Option C2, RC cantilever flood wall with seepage cut-off

5.3.4 Existing Bank Stability

As stated in Section 5.2.4 a preliminary slope analysis determined the extent of slope failure to be ~8m inland from the toe of the riverbank. Setting the floodwall back from the top of bank and out-with the slope failure zone / envelope would mitigate the need to carry out stabilisation work to the existing riverbank.

5.3.5 Utilities

As per Section 5.1.3 no utilities run parallel within the construction footprint for a flood defence set back from the existing bank, there are a number of crossing points where surface water outlet tails discharge into the River Carron and these can be extended through the flood defence with new head walls installed

5.3.6 Contaminated Ground Risk

No excavation of the existing bank is required as the piled wall is set-back from the back toe of the existing embankment which parallel to the riverbank. This option would leave the existing bank in-situ with only a small excavation required (leader trench) for the sheet piles.

5.4 Option D – Floodwall along Dalgrain Road, South Bridge Street and Grange Lane

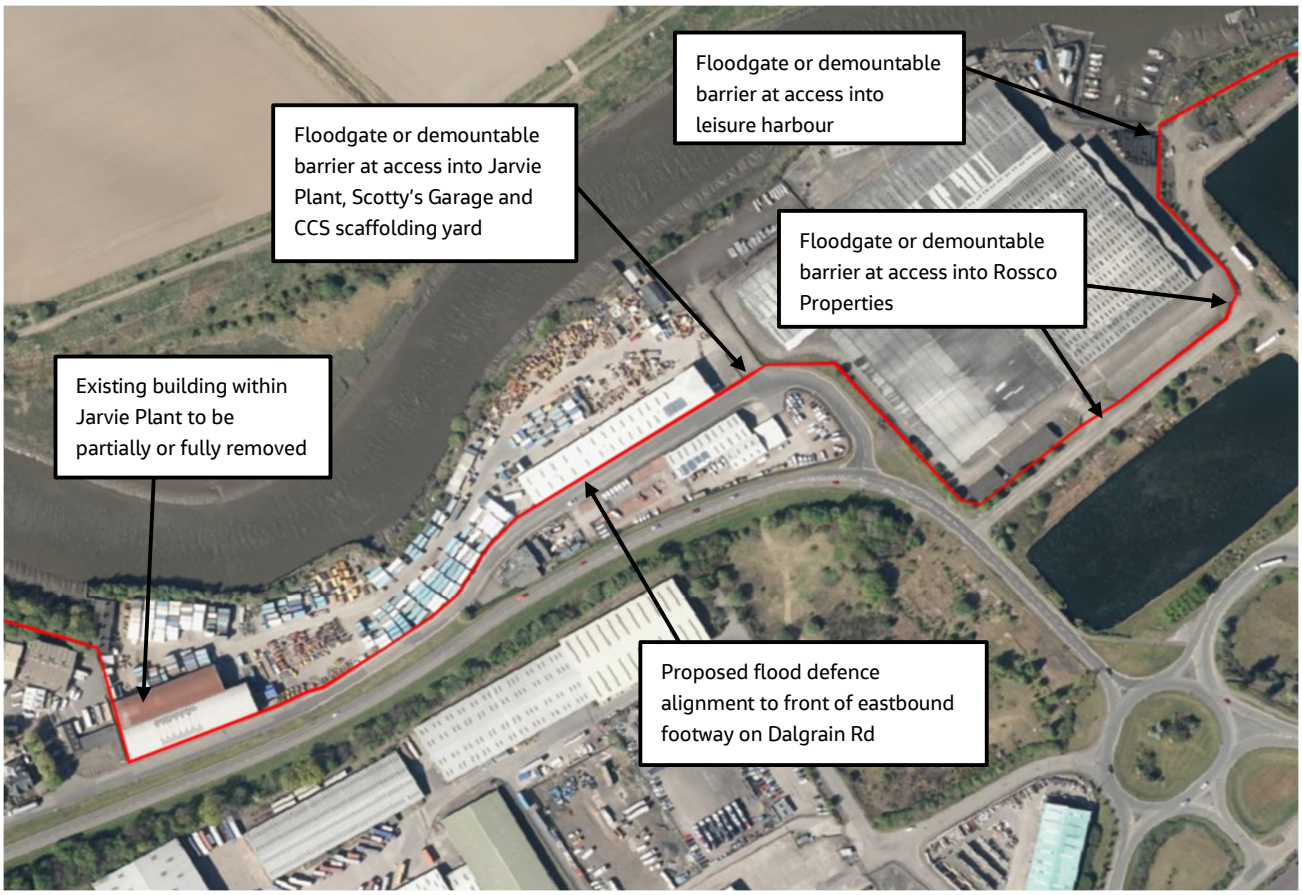

Figure 14: Flood defence alignment along Dalgrain Rd, South Bridge St. and Grange Lane

5.4.1 Description of Option D

This option moves the alignment away from the riverbank, reducing construction risk and the likely impact upon commercial operations to Jarvie Plant, Scotty's garage, CCS Scaffolding and Rossco Properties. Although, the existing shed structure at the southwest corner of the Jarvie Plant yard would need to be partially or fully demolished to allow for construction of the flood wall onto Dalgrain Road. Moving the flood defence alignment onto Dalgrain Road results in Jarvie Plant, Scotty's Garage, CCS Scaffolding and Rossco Properties all being left at risk of flooding.

The flood wall would be aligned parallel with the eastbound carriageway on Dalgrain Road. There are footways on both sides of the carriageway, the eastbound footway would need to be widened at sections to allow the floodwall to be set-back a suitable distance from existing buildings.

Several buildings form the boundary of the Jarvie Plant yard on Dalgrain Road. Offsetting the floodwall from existing buildings removes the risk of causing damage to the buildings and potential complicated liabilities. Further investigation would be required to the determine the foundation and condition of each structure which may impact the alignment of the flood wall.

Several floodgates / demountable barriers would be required at various access points along the length of the new flood wall.

5.4.2 Construction Option D1 – Steel sheet pile wall

A sheet piled wall allows for a smaller construction footprint and would require the existing footway/carriageway to be excavated. The minimum distance from the existing buildings to the wall alignment is ~1m, noise and vibration monitoring would be undertaken during the construction works period. From Ground Investigation works we estimate the embedment depth for a sheet pile wall would be ~8.5m.

The top of the sheet pile could be encased in concrete from just below ground level to the top of wall level, providing a reinforced concrete stem that can be clad in masonry or have an in-situ cast pattern profile finish.

Traffic management measures would be required along Dalgrain Road whilst construction works take place.

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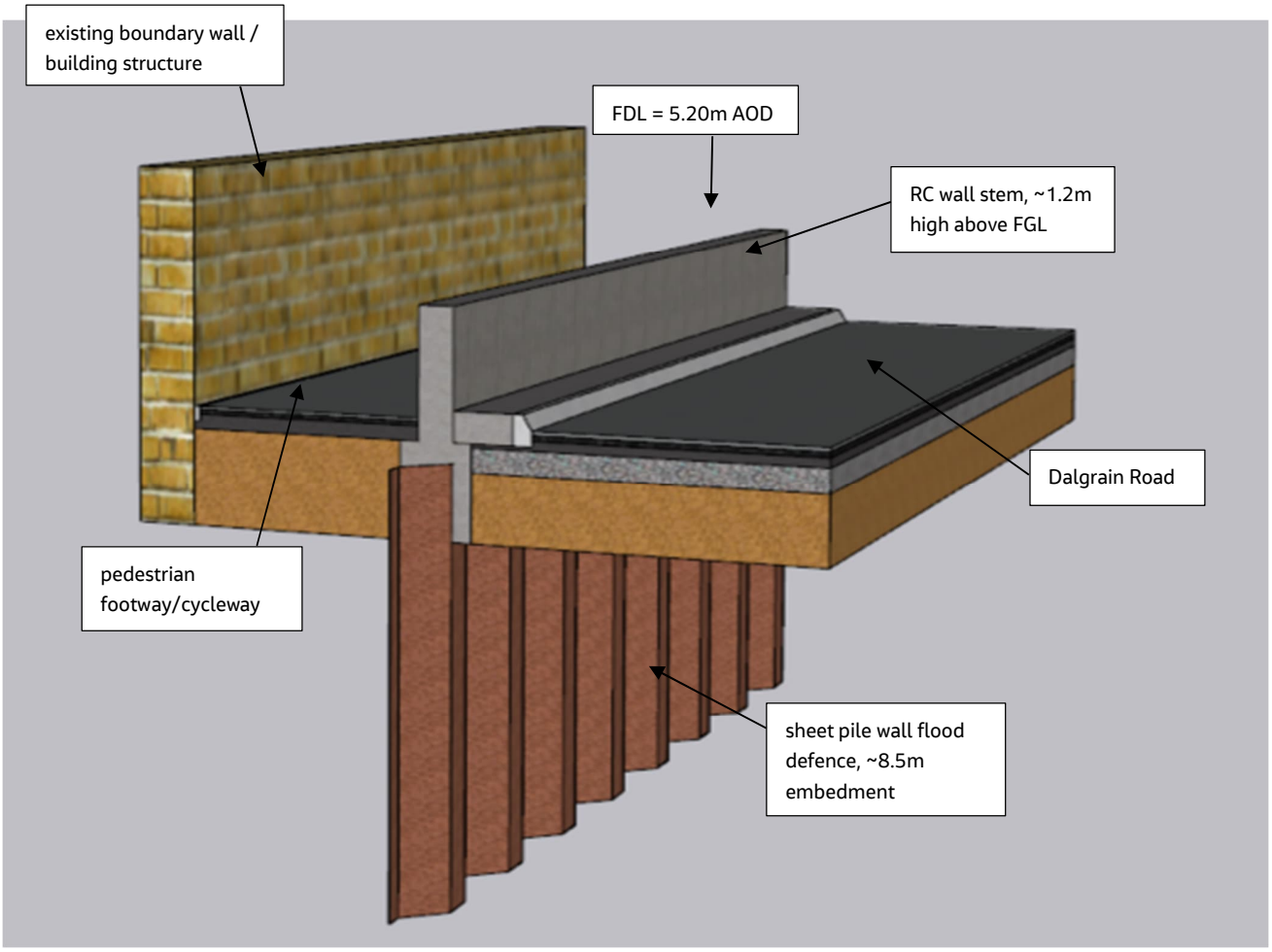

Figure 15: Option D1, sheet pile flood wall with RC stem

5.4.3 Construction Option D2 – Reinforced concrete cantilever wall

The construction of an in-situ reinforced concrete cantilever wall would involve excavation of the footway and part of the carriageway to a depth of ~1m. The wall would be founded on similar ground to Option C2 (Section 5.3.3) therefore, ground improvement methods would likely be required to increase strength of the existing ground or alternatively a piled foundation solution could be adopted. A seepage barrier would be required.

Temporary works would need to be provided to support adjacent buildings and part of the carriageway. Traffic management measures would be required along Dalgrain Road whilst construction works take place.

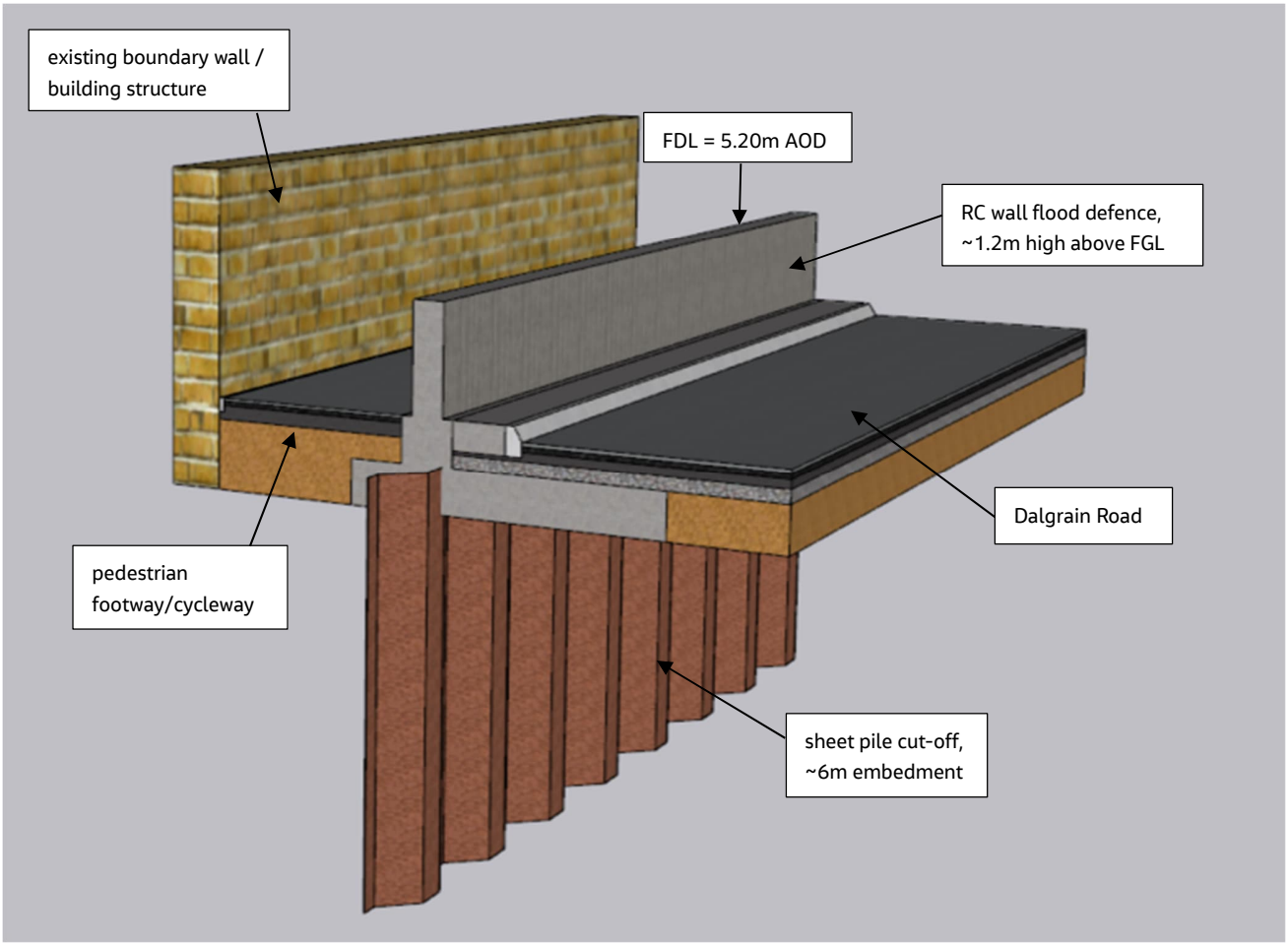

Figure 16: Option D2, RC cantilever flood wall with seepage cut-off

5.4.4 Utilities

Existing services would need to be diverted. All services within or close to the north side of the footway on Dalgrain Road/South Bridge St. would need to be diverted. Similarly, this would apply to all services within the footway on north side of Grange Lane and the access road to the Leisure Harbour.

The following table provides estimated costs for the diversion of services as described above:

Utilities	Length of Diversion (m)	Estimated cost (£)
Scottish Power (LV)	295	39,825
Scottish Power (HV)	394	73,284

Virgin Media	425	85,000
Scottish Water (Main)	474	357,870
British Telecom	55	22,000
Scottish Gas Network (LP)	45	14,040
Scottish Gas Network (IP)	176	253,088
Total estimated cost for diversions		845,107

Table 1: Cost Estimate for Service Diversions – Option 4

5.4.5 Contaminated Ground Risk

No excavation of the existing bank is required for this option, reducing the risk and exposure to contaminated ground.

5.5 Option E - Along Forth-Clyde Way, South Bridge St. and Grange Lane

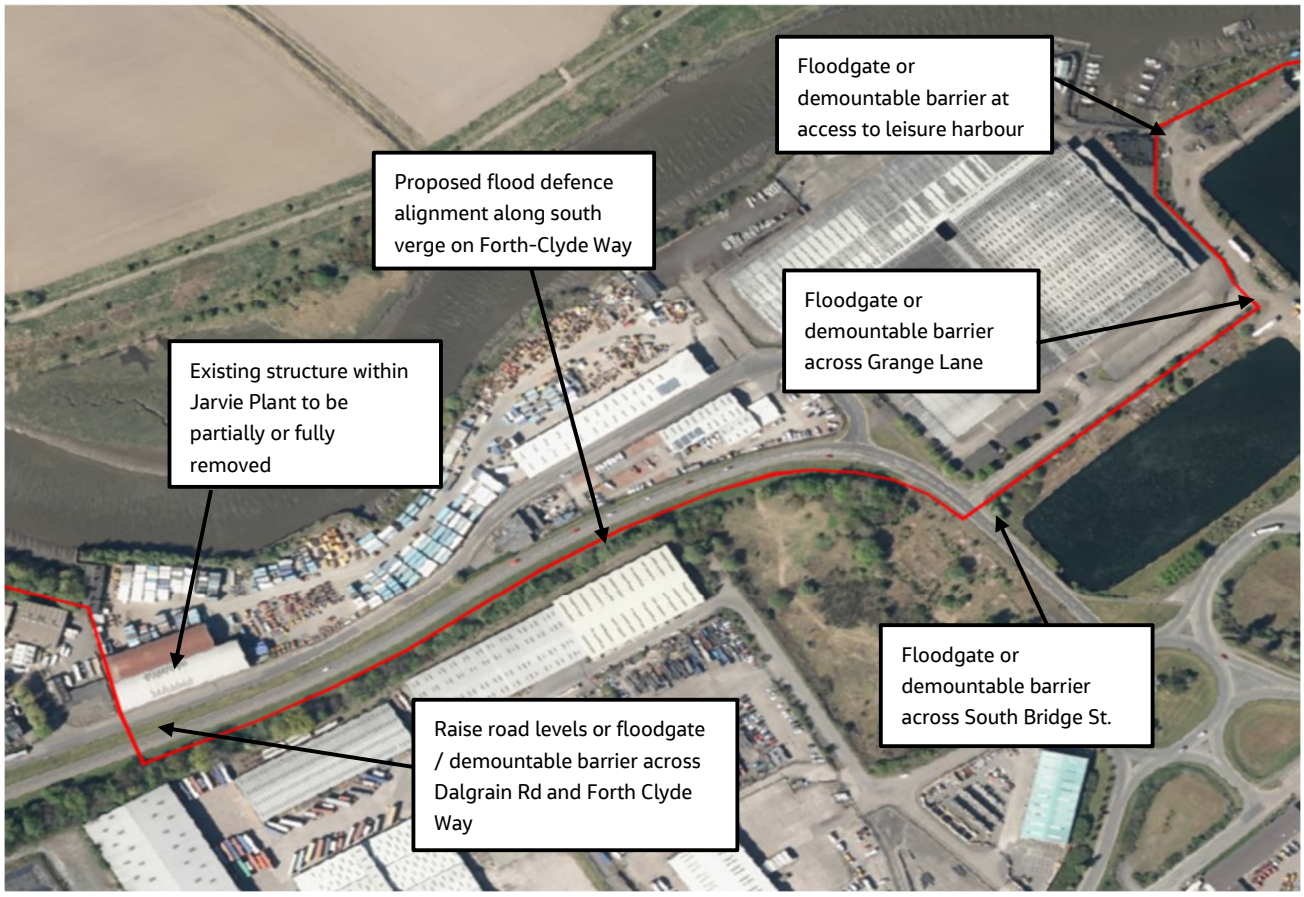

Figure 17: Alignment along Forth-Clyde Way, South Bridge St. and Grange Lane

5.5.1 Description of Option E

An alternative to Option D would be constructing a flood wall along Forth-Clyde Way, set back from the carriageway along either the north or south verge. Similar to Option D, having the alignment along Forth-Clyde Way results in Jarvie Plant, Scotty's Garage, CCS scaffolding and Rossco Properties all being at risk of flooding.

There is a narrow strip of land between Dalgrain Road and Forth-Clyde Way that contains multiple existing services that would need to be diverted at considerable expense. These costs could be avoided by constructing along the south verge of Forth-Clyde Way, which is a much wider strip of land and existing services appear to be located far enough back from the carriageway, allowing sufficient space to construct a floodwall without needing to divert services. Further investigation would need to be carried out to identify the exact location of these services.

The existing shed structure to the west of the Jarvie Plant yard would need to be partially or fully taken down to allow for construction of the floodwall onto Forth-Clyde Way. The flood defence will cross Dalgrain Road and Forth- Clyde Way, raising road levels locally or providing a demountable/permanent flood barrier would be required.

Along Dalgrain Road, road levels would be raised locally by ~0.9m to FDL (5.2m AOD), requiring a retaining structure along the eastbound carriageway, this may be avoided along the westbound carriageway where there

appears sufficient space to grade down to existing verge levels. Road levels on Forth-Clyde Way would be raised by ~0.3m to FDL, similarly the road could be supported by grading down to existing verge levels on either side of the carriageway. There are localised sections, towards the east along Forth-Clyde Way where road levels would need to be raised up to ~1.0m to have the carriageway above FDL. It is likely more feasible to raise the carriageway to the 200-year event without 0.6m freeboard. This would mean raising the road by ~0.4m, ensuring access can be maintained throughout a 200-year flood event. Alternatively, the road may be closed, and traffic diverted via Earls Road (A904).

5.5.2 Option E1 – Steel sheet piled wall

From Ground Investigation works we estimate the embedment depth for a sheet pile wall would be ~8.5m. The top of the sheet pile can be encased in concrete from just below ground level to the top of wall level, providing a reinforced concrete stem that can be clad in masonry or have an in-situ cast pattern profile finish.

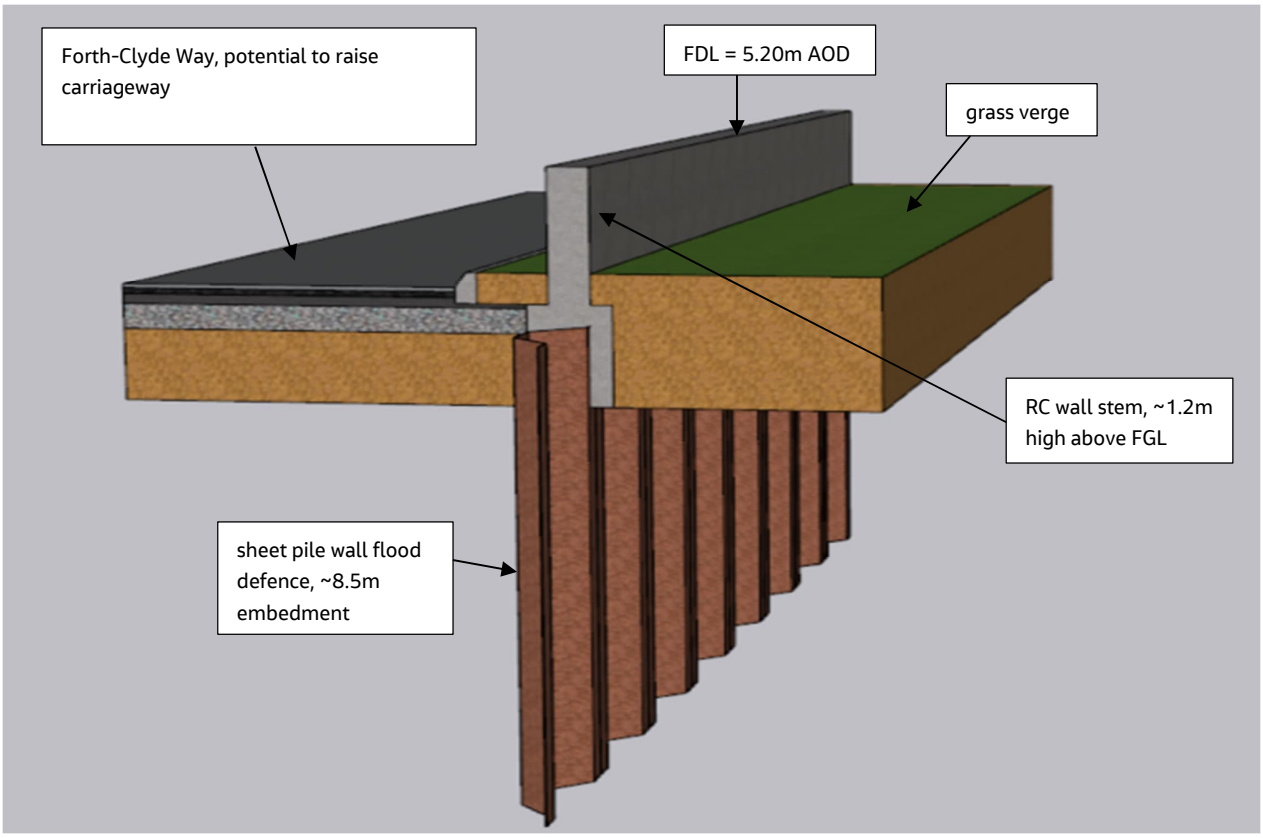

Figure 18: Option E1, sheet pile flood wall with RC stem

5.5.3 Option E2 – Reinforced concrete cantilever wall

The construction of an in-situ reinforced concrete cantilever wall would involve excavation of the verge and part of the carriageway to a depth of ~1m. The wall would be founded on similar ground to Option C2 (Section 5.3.3) therefore, a seepage barrier would be required. Temporary works would need to be provided to support the east-bound carriageway. Traffic management measures would be required along Forth-Clyde Way whilst construction works take place.

5.5.4 Utilities

The diversion of existing services along the south verge on Forth-Clyde way may be avoided due to sufficient space to construct a flood wall far enough back from the carriageway. Along the south side of Grange Lane there also appears to be sufficient space to construct a floodwall far enough back without interfering with existing services. Therefore, it is likely that only existing services within the access road to the Leisure Harbour be diverted.

The following table provides estimated costs for the diversion of services as described above:

Utilities	Length of Diversion (m)	Estimated cost (£)
Scottish Power (HV)	176	32,736
Scottish Gas Network (IP)	176	253,088
Total estimated cost for diversions		285,824

Table 2 Table 2: Cost Estimate for Service Diversions

5.5.5 Contaminated Ground Risk

No excavation of the existing bank is required for this option, reducing the risk and exposure to contaminated ground.

5.6 Comparing the Options

The following table highlights the main advantages and disadvantages for each proposed construction method, in conjunction with the proposed alignment options. The total cost shown is an estimate of the construction costs for building the flood defences and does not factor in the cost of preliminaries, traffic management, temporary works, and utility diversions. These costs are an approximated high-level estimate and should only be used for guidance within this technical note only.

Option	Form	Key Advantages	Key Disadvantages	Linear length of defence	Estimated Construction Cost (£M)
N/A	Do nothing	• No construction work • No disruption from construction work	• Area remains at risk of flooding, • Businesses periodically (frequently) incur the cost of flood damages	• 0m	To be confirmed

Option	Form	Key Advantages	Key Disadvantages	Linear length of defence	Estimated Construction Cost (£M)
A	Earth embankment with sheet-pile cut-off - along top of existing bank	• Aesthetically attractive • Long term stabilisation of riverbank • Protects all commercial properties	• Large permanent works footprint • Long construction time • Impact on commercial operations during course of works • Works within river channel • Significant excavation and removal of contaminated ground • Long term settlement and maintenance costs • Seepage protection is not incorporated	• ~750m	• £4.4 **Other costs not included** - temporary works, disposal of hazardous material
B1	Bare sheet-pile wall + riverbank stabilisation – along top of existing bank	• Low maintenance • Provision of seepage cut-off • Long term stabilisation of riverbank • Protects all commercial properties	• Long construction time • Impact on commercial operations during course of works • Works within river channel • Significant excavation and removal of contaminated soils • Depth of piles increases risk of hitting obstructions	• ~750m	• £4,.2 **Other costs not included** - temporary works, disposal of hazardous material
B2	RC cantilever wall with sheet-pile cut-off + riverbank stabilisation – along top of existing bank	• Low maintenance • Long term stabilisation of riverbank • Protects all commercial properties	• Large construction footprint • Works within river channel • Significant excavation and removal of contaminated soils • Long construction time	• ~750m	• £4.7 **Other costs not included** - temporary works, disposal of hazardous material

Option	Form	Key Advantages	Key Disadvantages	Linear length of defence	Estimated Construction Cost (£M)
			• Seepage cut-off separate to flood defence • Increased impact on commercial operations		
C1	Bare sheet-pile wall – setback from existing bank	• Speed of construction • Low maintenance • Provides seepage cut-off • Protects all commercial properties • Avoids riverbank stabilisation work • Avoids significant excavation and removal of contaminated soils • Avoids works within the river channel • Allows for riverside footway/cycleway	• Reduction of yard space within commercial premises, both temporary and permanent which could lead to significant compensation claims due to disruption to business	• ~750m	• £2.2 **Other costs not included** - footway/cycleway construction
C2	RC cantilever wall with sheet-pile cut-off – setback from existing bank	• Low maintenance • Avoids riverbank stabilisation work • Avoids works within the river channel • Allows for riverside footway/cycleway	• Large construction footprint • Long construction time • Reduction of yard space within commercial premises • Excavation and removal of contaminated soils • Seepage cut-off to be installed separately	• ~750m	• £2.5 **Other costs not included** - wall cladding, footway/cycleway construction, disposal of hazardous material and significant ground improvement works to create a platform for founding the wall base on
D1	Dressed sheet-pile wall + utility diversions	• Low maintenance • Provides seepage cut-off • Reduced impact on commercial operations during construction	• No protection to commercial properties • Utility Diversions • Risk of damage to existing buildings	• ~955m	• £4.3 **Other costs not included** - wall cladding, temporary works,

Option	Form	Key Advantages	Key Disadvantages	Linear length of defence	Estimated Construction Cost (£M)
			• Temporary works to support road carriageway • Removal of existing building within Jarvie Plant • Depth of piles increases risk of hitting obstructions		demolishing and rebuilding structures, Re-instatement of road pavement, flood gates/demountable barriers, traffic management
D2	RC cantilever wall with sheet-pile cut-off + utility diversions	• Low maintenance • Reduced impact on commercial operations during construction	• No protection to commercial properties • Utility Diversions • Risk of damage to existing buildings • Long construction time • Seepage cut-off to be installed separately • Temporary works to support buildings & road carriageway • Removal of existing building within Jarvie Plant	• ~955m	• £4.0 **Other costs not included** - wall cladding, temporary works, demolishing and rebuilding structures, Re-instatement of road pavement, flood gates/demountable barriers, traffic management
E1	Dressed sheet-pile wall + utility diversions	• Speed of construction • Low maintenance • Provision of seepage cut-off • Reduced impact on commercial operations during construction	• No protection to commercial properties • Closure of Dalgrain Road & Forth- Clyde Way during flood event • Removal of existing building within Jarvie Plant • Depth of piles increases risk of hitting obstructions	• ~950m	• £3.7 **Other costs not included** - wall cladding, temporary works, demolishing and rebuilding structures, flood gates, road construction, traffic management
E2	RC cantilever wall with sheet-pile cut-	• Low maintenance • Reduced impact on commercial operations during construction	• No protection to commercial properties	• ~950m	• £3.4 **Other costs not included** - wall

Option	Form	Key Advantages	Key Disadvantages	Linear length of defence	Estimated Construction Cost (£M)
	off + utility diversions		• Large construction footprint • Temporary works to support road carriageway • Closure of Dalgrain Road & Forth- Clyde Way during flood event • Removal of existing building within Jarvie Plant • Ground improvement works • Disposal of potentially contaminated ground		cladding, temporary works, demolishing and rebuilding structures, flood gates, road construction, traffic management and potential ground improvement works

Table 3 Comparison of option

5.7 Opportunities and Constraints Table

The nine options previously identified have been appraised considering economic, social, and environmental aspects. For simplicity a 3-point ranking was carried out ranging from low impact (green) to medium impact (orange) and high impact (red). The estimated construction costs are based on the figures in Table 4. Professional judgement, experience and a basic first principal's approach to determine the cost estimate, with key exclusions noted. The following bandings have been adapted for the construction cost; Low = 0- £2M, Medium = £2M - £4M, high = £4M+. No account for the costs of emergency services or costs incurred in recovering buildings have been included in the economic exclusions below.

Option	Length of flood defences (m)	Economics		Environmental	Potential exposure to contaminated ground	Comments
		Estimated Construction Cost (£)	Exclusions			
Do nothing	0	0		No construction work in the channel or on top of the bank.	High – the existing bank fails under flood conditions and exposes potentially contaminated ground which is distributed over a large area and possibly within the SPA.	Does not protect the commercial properties, or infrastructure in the area, would leave the Forth Clyde Boat Yard (Forth Ports land) at risk of flooding even if flood defence are constructed on the top of bank
A – Flood embankment along the top of the existing bank, existing bank reprofiled	750	High	Temporary works which would require some work within the channel	High – as the existing bank is removed and potential work is required from within the channel	High - the existing bank is removed and replaced	Significant work required to stabilise the existing bank, reduces the footprint of the Jarvie Plant yard

Option	Length of flood defences (m)	Economics		Environmental	Potential exposure to contaminated ground	Comments
		Estimated Construction Cost (£)	Exclusions			
B1 – Piled wall with reprofiled bank	750	High	Temporary works which would require some work within the channel	High – as the existing bank is removed and potential work is required from within the channel	High – the existing bank is removed and replaced	Significant work required to stabilise the existing bank, limits land take in the Jarvie Plant yard
B2– Piled and cantilever wall with reprofiled bank	750	High	Temporary works which would require some work within the channel	High – as the existing bank is removed and potential work is required from within the channel	High – at the existing bank is removed and replace and a cantilevered is required	Significant work required to stabilise the existing bank, reduces the footprint of the Jarvie Plant yard
C1 – Piled wall, set back from the existing bank	750	Medium	None to be included	Low - Existing bank remains in its current condition	Low – excavation limited to be leader trench only	Existing wall and bank remain in-situ, reduces the footprint of the Jarvie Plant yard
C2 – reinforced concrete cantilevered wall set back from the existing bank	750	Medium	Temporary works, dealing with material from the excavation, ground improvements to the made ground under the wall base	Low - Existing bank remains in its current condition	Medium – some excavation is required below the base of the wall	Existing wall and bank remain in-situ, reduces the footprint of the Jarvie Plant yard

Option	Length of flood defences (m)	Economics		Environmental	Potential exposure to contaminated ground	Comments
		Estimated Construction Cost (£)	Exclusions			
D1 – Piled wall at the edge of Dalgrain Road	955	High	wall cladding, temporary works, demolishing and rebuilding structures, Re-instatement of road pavement, flood gates/demountable barriers, traffic management	Low - Existing bank remains in its current condition	Low – due to the limited excavation required. The location of the wall is outside the Jarvie Plant site	Existing wall and bank remain in-situ, no impact on the Jarvie Plant yard
D2 – Reinforced concrete wall at the edge of Dalgrain Road	955	High	wall cladding, temporary works, demolishing and rebuilding structures, Re-instatement of road pavement, flood gates/demountable barriers, traffic management	Low - Existing bank remains in its current condition	Medium – some excavation is required below the base of the wall, all excavation is outside the Jarvie Plant site	Existing wall and bank remain in-situ, no impact on the Jarvie Plant yard
E1 – Piled wall at the edge of Forth Clyde Way	950	Medium	wall cladding, temporary works, demolishing and rebuilding structures, flood gates, road construction, traffic management	Low - Existing bank remains in its current condition	Low – due to the limited excavation required. The location of the wall is outside the Jarvie Plant site	Existing wall and bank remain in-situ, no impact on the Jarvie Plant yard
E2 – Reinforced concrete wall at the edge of Forth Clyde Way	950	Medium	wall cladding, temporary works, demolishing and rebuilding structures, flood gates, road construction, traffic management	Low - Existing bank remains in its current condition	Medium – some excavation is required below the base of the wall, all excavation is outside the Jarvie Plant site	Existing wall and bank remain in-situ, no impact on the Jarvie Plant yard

Table 4: High-level assessment of the nine options

6. Discussion

6.1 Construction Method

This technical note has outlined four methods of constructing flood defences, and five flood defence alignment options.

The forms (methods) of construction considered for the four alignment options are as follows:

- Earth embankment with sheet-pile cut-off
- Sheet pile wall (exposed above ground)
- Sheet pile wall with reinforced concrete stem
- Cast In-situ reinforced concrete cantilever wall with sheet-pile cut-off.

The construction of a flood defence setback from the existing riverbank (Option C) would be the most straight forward from a construction aspect, additionally, this form of construction is the quickest, there is no need for reinforced concrete. The preferred form of construction would be Option C1 – steel sheet piles which would be exposed above ground (bare). This method of construction would reduce the potential for encountering contaminated ground, as the only excavation required would be the leader trench.

Options A and B requires the existing bank to be excavated and re-profiled, this would increase the exposure risk of encountering contaminated ground, but also require remedial work to process potentially contaminated ground and if required dispose of material at an appropriate facility. Both options would increase the complexity of the construction work, and require some work from within the river channel, which would need significant temporary works to be installed. The construction works in options A and B would take significantly more time than option C and are reflected in the estimated construction costs.

The construction methods associated with options D and E would be more time consuming than option C, as the wall needs to be clad. Traffic management measures would also need to be considered.

6.2 Alignment Option

6.2.1 Jarvie Plant

Where practical the flood defence should be set back from the bank top, to reduce the potential exposure to contaminated ground, The existing riverbank would need to be monitored for erosion over the design life of the flood defences to ensure the flood wall is not undermined should significant erosion occur. The design team have used a worst-case scenario (whereby the existing bank has failed) to determine the pile length and ensure the flood wall would still be structurally sound in the event the existing bank fails. Aligning the flood wall ~5m from landward toe of existing bund, means the wall is completely independent from the existing bank and out-with the slope failure envelope. Option C1, would be the fastest to construct, but would require a 5m strip of land in the Jarvie Plant yard to be permanently lost. Options A and B are likely to have a greater impact on the Jarvie Plant yard whilst construction works are ongoing. Option A would reduce the permanent footprint of the Jarvie Plant, where as option B would allow the current yard area to be maintained. Options D and E do not alter the Jarvie Plant yard.

Figure 19 flood defence alignment through Jarvie Plant Yard

6.2.2 Scotty's Garage

Due to the proximity of the building (garage workshop) to the top of the existing bank and the limited access to the bank mean constructing a wall to protect Scotty's Garage is not a viable option. The proposed wall will replace an existing masonry wall and follow the Jarvie Plant boundary fence, meaning Scotty's Garage is on the wet side of the wall. A flood gates will be required to maintain access. By locating the wall away from the existing bank, pile lengths can be reduced as the pile has been designed with no passive resistance in place, as well as reducing the potential for encountering contaminated ground. Options D and E are set-back from Scotty's Garage and would not directly impact the garage.

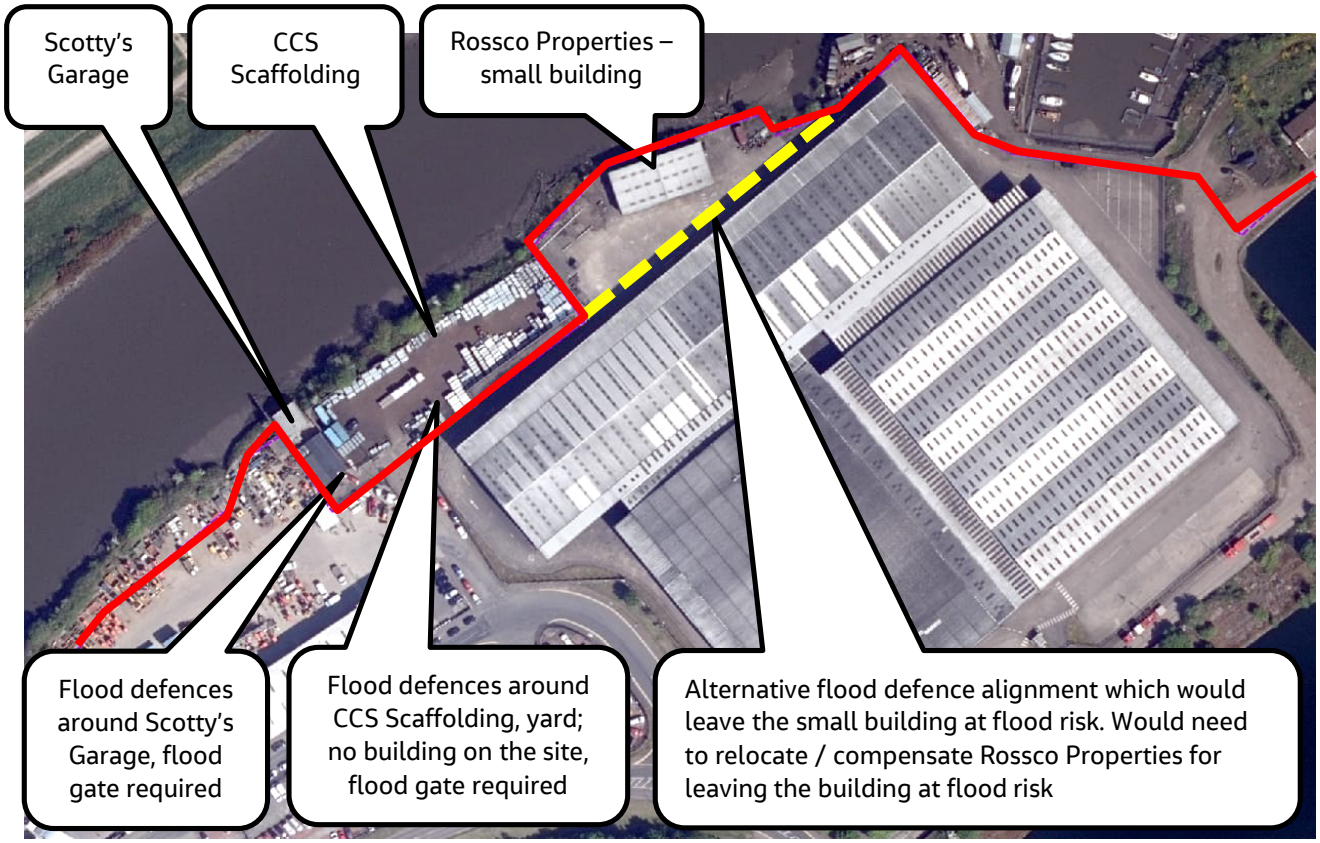

Figure 20 outlines the flood defence alignment covering Scotty's Garage, CCS Scaffolding and Rossco Properties

6.2.3 CCS Scaffolding Yard

To avoid constructing the flood defences from within the channel (River Carron) the flood defence wall will replace the southern boundary fence of the yard. This will leave the yard at risk of flooding (there are no buildings within the yard). A flood gate will be required to maintain access into the yard. This alignment will also reduce the potential for encountering contaminated ground and allow for a simpler form of construction.

6.2.4 Rossco Properties Site

Further discussions with Rossco Properties are required to fully understand how the site is used and if the small building close the bank top is actively used. Figure 20 shows the flood defence to the north of the building (protecting it) but this would require significant temporary works to allow construction work to take place from within the river channel, with the possibility of damaging the building during the construction phase. It is more practical to relocate the building or straighten the alignment of the flood defences in this area to not protect the building.

6.3 Options D and E

Adopting options D or E may reduce the direct impact on landowners, but none of the commercial properties in this area would be protected from flood risk. Currently some properties along Dalgrain Road are at risk of flooding from a 1 in 5-year baseline event with all at areas at risk from the 1 in 10-year baseline event. The preferred form of construction would be option E1 – steel sheet pile wall with reinforced concrete stem above ground. This option allows for the wall to have a pattern concrete finish which is more compatible with the surrounding environment.

Adopting a sheet pile solution along Forth-Clyde Way allows for a faster construction period, mitigates the need for service diversions and temporary works to support the road carriageway during the works, reducing the construction footprint and removes the need for ground improvement measures.

This option also limits the need for flood gates or demountable barriers to maintain existing access into commercial premises.

6.4 Impact on Landowners

The options outlined in this technical note are likely to affect several landowners. Some landowners will be directly affected both by temporary loss of space during the construction phase, but also permanently as the flood defences will reduce the operational size of their site. It is important to consider the potential impacts on landowners when accessing options. It is likely that landowners who are permanently impacted by the scheme will look to Falkirk Council to compensate them through a financial settlement or offer of an alternative site. Further discussions with landowners is required to determine what kind of impact that scheme may have on their business. Under the FRMA, landowners are required to submit a claim for compensation, rather than Falkirk Council proposing a compensation settlement.

6.5 Do Nothing

The baseline flood risk is outlined in section 3.1, with the onset of flooding starting for a 5 to10 year event. This represents a high frequency of flooding. All the commercial properties would remain at risk of flooding.

7. Conclusion

Option C1 - sheet pile flood wall set-back from top of the existing riverbank has been selected as the option that should be progressed subject to discussion with landowners.

8. Recommendations

The recommendations outlined in this technical note should be viewed as an interim recommendation. Once the actions outlined in Section 11 (Next Steps) are completed, the recommendations in this technical note should be reviewed with any necessary amendments made.

The interim recommendation is that Option C and construction method C1 - sheet pile flood wall set-back from top of the existing riverbank should be progressed subject to the following:

- Falkirk Council agree with the recommendation,
- understand what impact a reduced size of yard would have on Jarvie Plants' operations, this may require a feasibility scoping study of potential alternative sites,
- understand what impact the scheme will have on Scotty's Garage, and what alternative measures could be implemented,
- understand what impact the scheme will have on the Rossco Properties site, and what alternative measures could be implemented,
- meet all affected landowners to discuss alignment Option 'C' if this is not acceptable to the landowners propose Option 'E'. Update technical note following the outcomes from some of the above recommendations.

9. Design Principals

Tabel * outlines the scheme design principals, which have been developed to help the design team determine the alignment of flood defences. The three alignment options have been considered for this technical note.

Alignment Principles		Alignment Options				
		A	B	C	D	E
1	Protect existing buildings and infrastructure	✓	✓	✓	✗	✗
2	Avoid encroachment into sensitive environmental sites	✗	✗	✓	✓	✓
3	Minimise disturbance of existing riverbanks and coastline	✗	✗	✓	✓	✓
4	Retain existing undeveloped land/ flood plains	✗	✗	✗	✓	✓
5	Avoid in water working	✗	✗	✓	✓	✓
6	Avoid utility diversions	✓	✓	✓	✗	✗
7	Locating flood defence adjacent to residential properties and outside the residential property boundary to reduce the	✓	✓	✓	✓	✓
8	Locating flood defences out-with the operation areas of the petrochemical site	N/A				
9	Retain passive resistance to embedded walls to reduce pile lengths	✗	✗	✓	✓	✓
10	Consider Loading, Form of Defence and Land Take	✓	✓	✗	✓	✓
11	Adopt solutions that minimise disturbance of contaminated soils	✗	✗	✓	✓	✓
12	Maintain a straight alignment where possible e.g., avoid frequent changes in direction	✓	✓	✗	✗	✗
13	Minimise the use of floodgates and demountable defences	✓	✓	✓	✗	✗
14	Maintain a consistent standard of protection	✓	✓	✓	✓	✓
15	Avoid tree felling and vegetation clearance	✗	✗	✓	✓	✓
16	Consideration of future maintenance and access requirements	✓	✓	✓	✓	✓
17	Ensure the residual pluvial flood risk is appropriately mitigated	✗	✗	✗	✓	✓

Alignment Principles		Alignment Options				
		A	B	C	D	E
18	Ensure key transport arteries are resilient to a 200yr event	✓	✓	✓	✓	✗
19	Minimise impact on the road network	✓	✓	✓	✗	✗
20	Minimise impact on cultural heritage sites	N/A				

Table 5 Design Principals

10. Equality Poverty Impact Assessment

An equality poverty impact assessment (EPIA) is being undertaken at key project milestones. The EPIA contained within this technical note, will feed into the over EPIA for the project. The EPIA (Table 6) is a high-level assessment that is bespoke to this technical note and option C1 which has been recommended as the option that should be progressed beyond the outline design stage.

Protected Characteristic	Neutral Impact	Positive Impact	Negative Impact	Evidence of impact on protected characteristic
Age				Positive impact – reduces flood risk to communities in the Grangemouth/Glensbrugh area.
Disability				
Sex				No impact
Ethnicity				No impact
Religion/belief				No impact
Sexual Orientation				No impact
Transgender				No impact
Pregnancy/maternity				No impact
Marriage/Civil Partnership				No impact
Poverty				Positive impact - Grangemouth has high indices of multiple deprivation and will protect those less readily able to prepare, protect and recover from flooding. The scheme will provide flood protection to communities in Grangemouth, which aims to stimulate economic growth and generate additional employment opportunities.
Health/community justice				

Table 6 Equality poverty impact assessment for Option C1.