Bedminster Green River Restoration & Flood Alleviation

Options Appraisal

Draft Report

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Revision history

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27/11/2018	Draft Report	Patrick Goodey, Matt Sugden (BCC)

Contract

This report describes work commissioned by Matthew Sugden, on behalf of Bristol City Council, by an e-mail dated 4th October 2017. Bristol City Council's representative for the contract was Matthew Sugden. Daryl Taylor and Anissia Halwyn of JBA Consulting carried out this work.

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Purpose

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1 Introduction

1.1 Study Purpose

JBA was commissioned by Bristol City Council to investigate options for improving the quality of the River Malago and delivering flood risk benefits, as part of a wider redevelopment of the Bedminster Green area.

The River Malago flows along the south and eastern boundary of the proposed regeneration area, with approximately 140m of the total 415m length through the site being culverted.

1.2 Study Location

The study location is shown in Figure 1-1. The extent of the proposed redevelopment is shown by the blue polygon, whilst the red polygon represents the development plots which include the River Malago and so might be affected by any proposals.

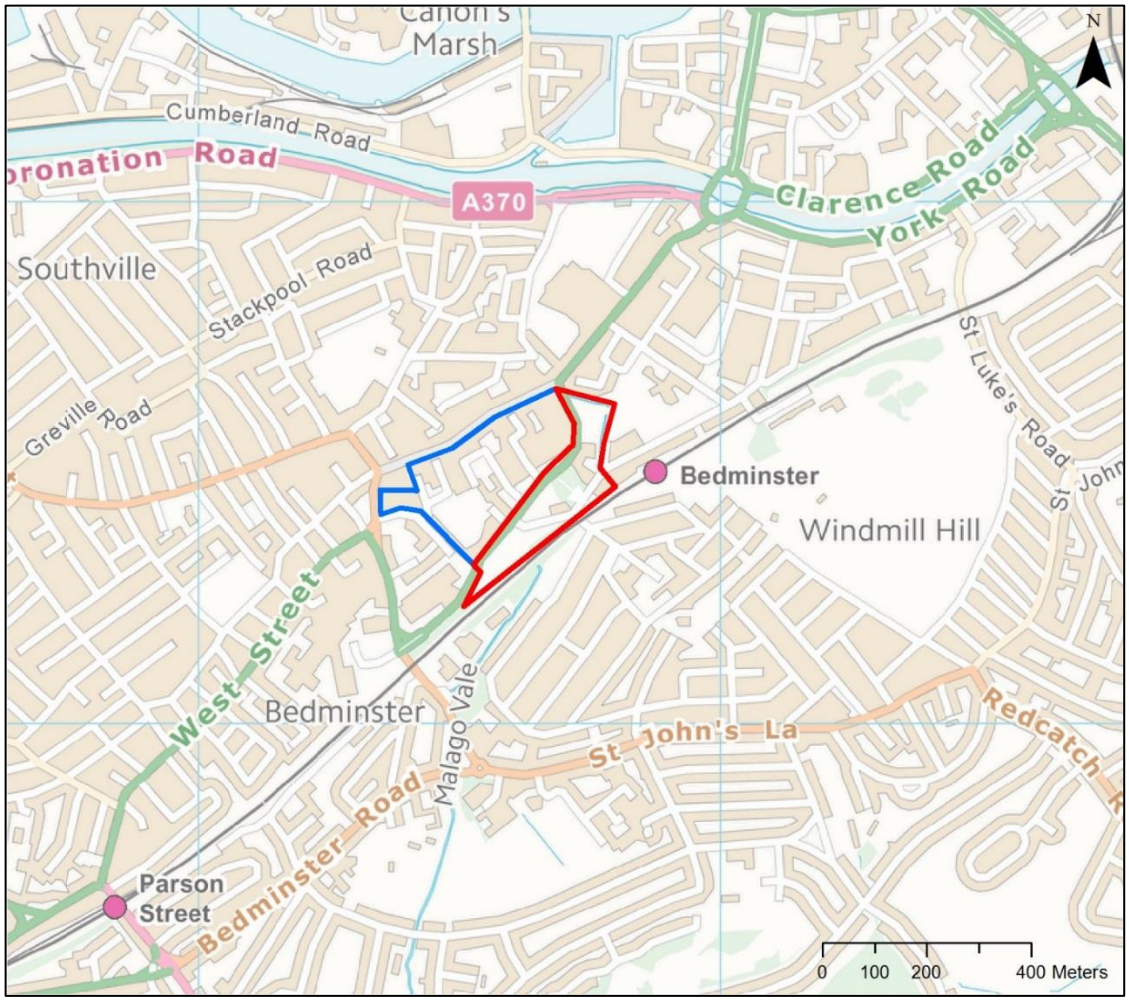


Figure 1-1: Study Location

1.3 Study Objectives

Objectives for the study, agreed between JBA and Bristol City Council, are as follows:

- Carry out a baseline assessment of flood risk from the River Malago and assess the current morphological condition of the river in the vicinity of the site.
- Develop and appraise options to improve the condition of the River Malago and provide flood risk reduction benefits.
- Select a preferred option and assess its potential benefits, including economic analysis.

2 Baseline Hydromorphic Assessment

A field-based hydromorphic (fluvial) assessment of the River Malago in Bedminster was conducted on 25 October 2017, the extent of which is shown in Figure 2-1. The assessment places the character and dynamics of the river in the historic context of channel engineering and management. It considers the current hydromorphic condition of the river, its response to and consequences of potential options to improve the condition of the river within the regeneration site.

Changes occurring to a river are a function of both local controls on flow pattern and energy concentration and other wider catchment controls on flow magnitude, frequency and sediment transport. A study of the dynamic fluvial geomorphology of a catchment provides an integrated perspective, as well as a rigorous understanding of the physical processes by which the river channel is formed and alters. This approach also recognises and assesses the importance of history and site-specific conditions, critical to the success of river engineering and management. This understanding can be achieved through desk and field-based survey methodologies, which follow broad Environment Agency guidelines. Sources of information include web based aerial photographic evidence, planform change information from Ordnance Survey maps and a walkover of the study reach. This allows a conceptual model of system functioning to be developed.

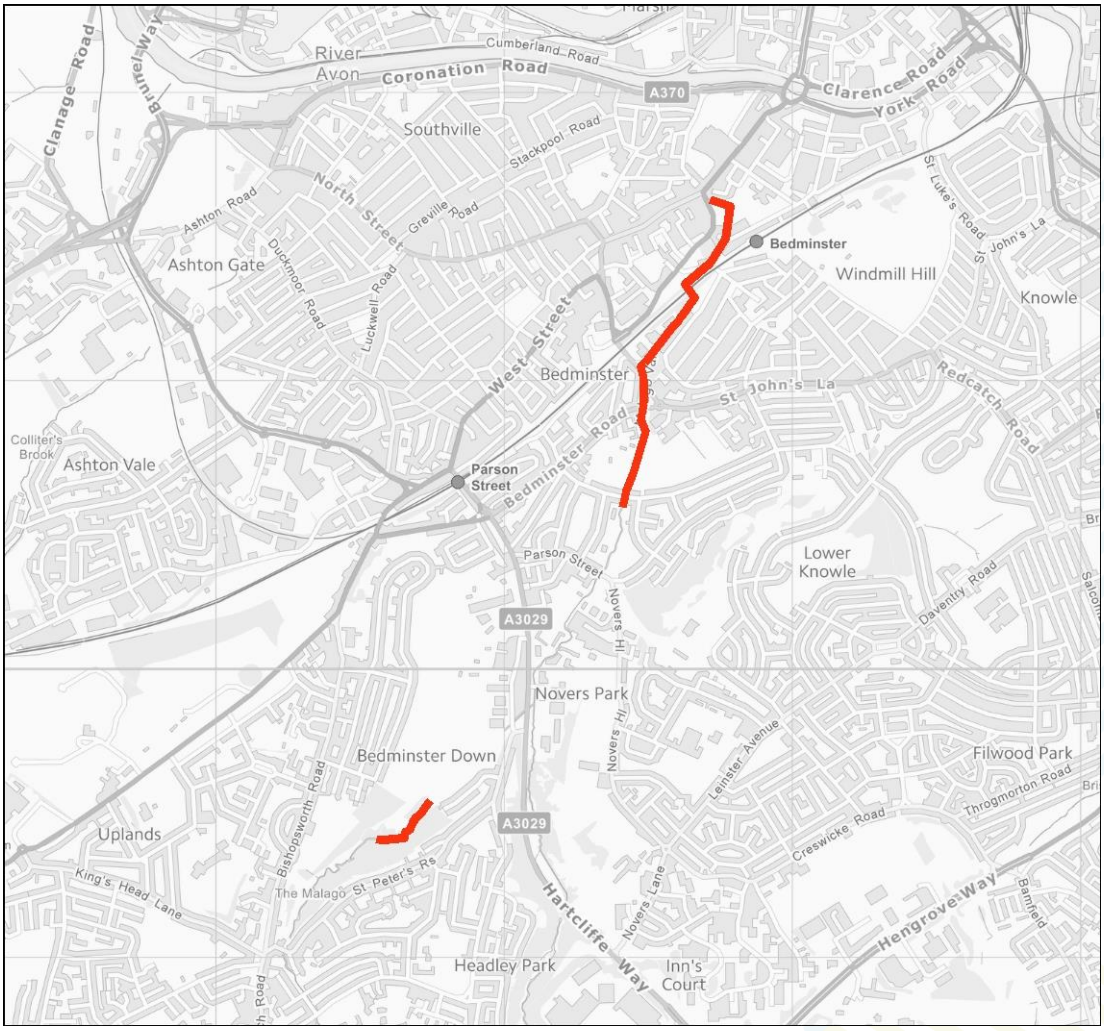


Figure 2-1: Walkover extent

2.1 Catchment Character

The River Malago has a total catchment area of approximately 18km^2 from its confluence with the River Avon. The catchment comprises two notable watercourses, the River Malago and the Pigeonhouse Stream, the confluence of which is located immediately to the south of Bedminster Fire Station.

Both watercourses have their sources on Dundry Hill, a rural area just to the south of Bristol. The uppermost areas of the catchment comprises large arable fields, before descending into smaller pasture and fallow fields on the approach to the urban area of Bristol. In this area, there are numerous small streams and the catchment is steep, flowing in a generally northerly direction. Upstream of Bristol, the Pigeonhouse Stream is a more developed watercourse, having already several tributaries, whilst the Malago remains as several distinct streams.

Where the streams meet the southern extent of the Bristol urban area, they enter culverts and are conveyed for a significant length in a northward direction with only a very short open channel section on the Pigeonhouse Stream at Hartcliffe. Within these culverts, there are numerous confluences and a significant number of surface water outfalls from the areas of Hartcliffe and Whitchurch (to the Pigeonhouse Stream) and Withywood (to the River Malago). Both watercourses return to open channels a short distance to the north of Hengrove Way, with the Pigeonhouse Stream flowing into the lake adjacent to the Imperial Park development and the River Malago emerging near Headley Road allotments.

From the allotments the River Malago flows in a small open channel with frequent short culverts beneath residential highways and then opens up into Manor Woods Valley Park to the north of Headley Park Church. Through the park, the channel is fairly natural in character and flows through a wooded area. Approximately 500m along the length of this reach, a large sediment trap has been constructed which functions as a weir (Figure 2-2). The channel immediately downstream of the sediment trap has been modified with a concrete or block stone invert and revetments in places. At the downstream end of the Manor Woods Park reach, the River Malago joins the Malago Storm Interceptor where it flows into a large culvert, remaining underground until its confluence with the River Avon.

Figure 2-2: River Malago sediment trap

Downstream of the Imperial Park lake, the Pigeonhouse Stream flows as a fairly naturalised wooded stream for approximately 500m through Crox Bottom Park. Approximately midway along this reach, there is a small pool with a weir outlet followed by a small channel ending with a large trash screen which forms part of the Malago Interceptor. Low flows are able to pass downstream via a small opening, with excess flows overflowing into large rectangular openings and falling into the Malago Interceptor culvert.

The low flows from the Pigeonhouse Stream cross the A4174 in a culvert, discharging into a short length of artificial open channel and then into a semi-natural tree-lined channel via a short culvert. The stream continues northward, flowing parallel to the A4174, to its confluence with the former River Malago channel which now drains surface water from nearby residential development.

From this location, the stream flows north-east for approximately 400m and is constrained to a small tree lined channel surrounded by industrial development as far as Parson Street. To the north of Parson Street, the left bank of the channel is sub-urban residential development with a public park on the right banks and retains a similar character for approximately 1km as far as Bedminster Road.

Downstream of Bedminster Road, the catchment slopes become significantly shallower and the surrounding land uses becomes more dense and urban, with typically industrial and commercial developments adjacent to the channel. After flowing into a culvert beneath the railway, the waterway is heavily modified and straightened with engineered banks. The watercourse is culverted in the vicinity of Hereford Street, before entering an open channel reach at Clarke Street and then a long culvert at Dalby Avenue which discharges into the River Avon.

2.2 Historic trend analysis

The River Malago has been modified significantly through its urban reaches and has been subject to historic straightening, culverting and loss of riparian zones.

Historic mapping and the local topography indicates that the natural alignment of the River Malago is roughly along its current course as far downstream as St Johns Lane. Below this point, the river continued to meander northward to a point near the St Johns Road / Coronation Road junction.

Mapping appears to indicate that in 1750, there was an offtake or drainage channel which flowed alongside Bedminster Parade. Between 1750 and 1828, the river was culverted form Charlotte Street to the Avon and also along Bedminster parade. A number of mill leats and other offtakes are visible in the 1828 mapping, serving local mills and industrial premises, including one flowing along the route of the current open channel along the eastern boundary of the development site. Up to the 1880s, the route of the lower Malago remained fairly constant, although the extent of culverting progressively increased as development and industrialisation of the surroundings increased.

Between the 1880s and the 1900s, the river was almost entirely culverted, and the extent of open channel has remained similar to the current day. Culverts were retained at Willway Street and Sheene Road, both functioning as flood reliefs from the open channel. A sluice gate is present on the bend of the channel at Sheene Road (Figure 2-3), however this sluice gate is now inoperable and is locked in the closed position.

Upstream of St Johns Road, the river previously meandered where playing fields now exist between Lynton Road and Bedminster Road, but approximately 500m of the river has been straightened in the last 50 years (Figure 2-4).

Following a significant flood event in 1968, when 800 properties were flooded and seven people killed, the Malago and Pigeonhouse Stream Interceptors were constructed to divert flood floodwater into the River Avon and reduce flood risk to the south of Bristol. One interceptor is located on the Malago to the northwest of Manor Woods in Bedminster Down and another is on the Pigeonhouse Stream at Hartcliffe Way.

The location of the interceptors and retained flood relief culverts is shown in Figure 2-5.

The effect of the interceptors has been to significantly reduce the flows passed to the lower Malago from the upstream catchment, both in dry weather and flood conditions. The Malago interceptor intercepts all flows from the stream, whilst the Pigeonhouse interceptor maintains a low flow in dry weather via a 350mm diameter opening. Flows in the Lower Malago are typically driven by the urban drainage network which discharges in the river at several locations.

Figure 2-3: Victorian sluice at Sheene Road

Figure 2-4: Straightened channel between Parson Street and Bedminster Road

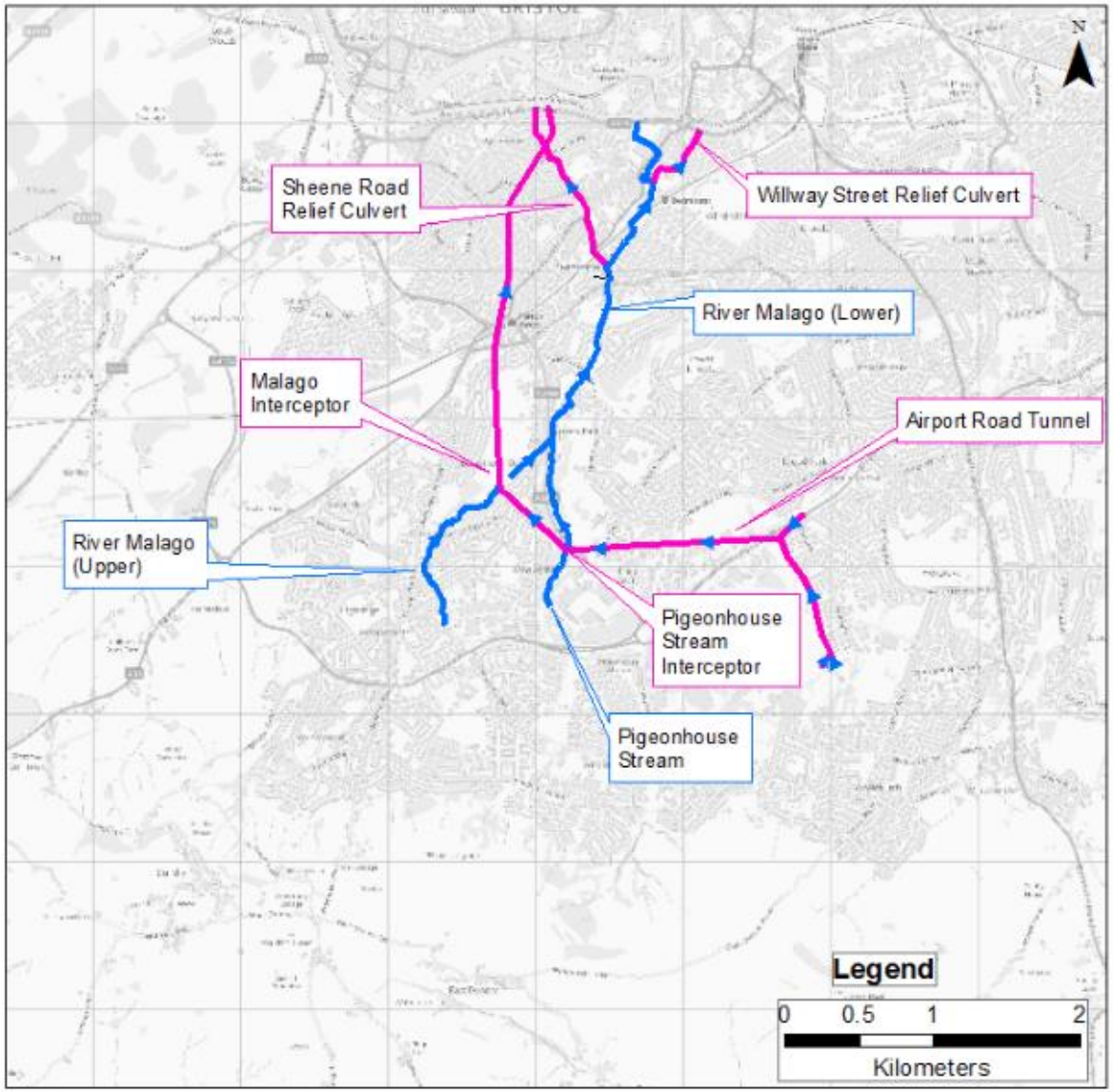


Figure 2-5: Interceptors and flood relief culverts on the Malago

2.3 Current hydromorphic condition and processes

Throughout the majority of the study reach downstream of the interceptors, the River Malago is a modified urban channel displaying hydromorphological features and characteristics which are a result of significant past historic modification and management activities, primarily the impacts of the mills and associated structures.

Flow in the channel is very low due to the presence of the interceptors. The channel has been historically straightened and widened in many sections, all of which have limited hydromorphic diversity.

Although sediment on the channel bed contains cobbles (probably artificial materials) and gravels, a layer of deposited silt indicates a reduced capacity for sediment transport. Floodplain connectivity is largely reduced due to the presence of walls lining the banks in many sections. Where unprotected, the banks are composed of compacted soils. There is no evidence of significant bank or bed erosion within the study reach.

Reduced flows have caused vegetation overgrowth within the channel in some sections, particularly where the banks are unprotected (e.g. Figure 2-4).

Overall, the morphological condition of the Lower Malago is considered to be poor, resulting from the unnatural flow regime and the widening and straightening of the channel leading to very low flow velocities.

3 Baseline Assessment of Flood Risk

Results from the Central Area Flood Risk Assessment (CAFRA) hydraulic model were used to assess the current level of flood risk to the development site. The CAFRA model is a 1D-2D hydraulic model which covers all of the major watercourses within Bristol city, including the Malago and allows flood risk from both fluvial and tidal sources to be assessed.

3.1 Review of CAFRA model

Whilst it is built on detailed survey and with detailed hydraulics, the CAFRA model remains a strategic level model for use across Bristol City and so a brief review of its suitability for use in this study was carried out.

3.1.1 Model Geometry

Within the study area, the hydraulic model is built using cross-section survey collected in March 2011. No significant changes are understood to have occurred within the River Malago channel in the vicinity of the site since the date of the survey and so the survey is considered to be representative of the current conditions.

Cross-section spacing in the model (approximately 100m) is relatively large for such a narrow river channel. However, due to its artificial nature and the very shallow longitudinal slope, very little variability in form is found in the Malago channel. Therefore, the model cross-sections are considered to be representative of reality in the vicinity of the site.

Consequently, the model geometry is considered appropriate for use in its supplied form.

3.1.2 Model Schematisation

A full review of model schematisation was not carried out, as the model has previously been peer reviewed, however the schematisation of structures within the study reach was carried out and this appears appropriate.

Based on observations of the channel during a site visit, roughness parameters in the vicinity of the channel appear appropriate.

Therefore, the model schematisation is considered appropriate for use in its supplied form.

3.1.3 Model Hydrology

The supplied model uses design inflows calculated using the FEH Statistical method, fitted to hydrograph shapes derived using the ReFH1 model. The decommissioned flow gauge at Parson Street was used as a donor catchment for the statistical analysis.

A review of the hydrology identified factors which would make the supplied hydrology unsuitable for this study, notably:

- Use of the Parson Street Gauge. The gauge record available is for 1956 – 1974, prior to the construction of the Malago Interceptor and so is not suitable for the lower catchment in which the study area is located
- Use of FEH Statistical method. The complex drainage, including the influence of the Interceptors and Combined Sewer Overflows (CSOs), will make a confident lumped flow estimate using the Statistical method difficult to achieve. There are no gauges monitoring the flow upstream and downstream of the

Interceptors. This all points to a rainfall-runoff approach, applied in a semi-distributed way, being preferred

Therefore, it was agreed that design flow estimates for the Lower Malago and Pigeonhouse Streams (i.e. downstream of the Interceptors) would be updated using the Urban ReFH methodology. This method allows catchments to be divided into sub-catchments based on the sewer network, with different flow characteristics:

- Undeveloped areas
- Urban areas where both the topography and sewers drain towards the watercourse
- Urban areas where the topography drains towards the watercourse but sewers drain out of the catchment ('sewers out')
- Urban areas where sewers drain into the watercourse from outside the topographic catchment ('sewers in')

A comparison of the peak flow estimates in the existing CAFRA model and the updated Urban ReFH flows was carried out.

AEP	CAFRA Peak Flow (m^3/s)	Urban ReFH Peak Flow (m^3/s)
50%	3.44	1.96
20%	4.77	2.82
10%	6.17	3.48
4%	7.46	4.92
1.33%	10.09	8.54
1%	10.91	9.71
0.5%	13.19	12.82
0.2%	16.98	18.00
0.1%	20.59	22.58

Table 3-1: Comparison of Previous and updated Malago Inflows

It can be seen that the updated hydrology shows a reduction in flows in smaller events and an increase in the most extreme events when compared with the CAFRA model inflows, with flows remaining similar in the design event (i.e. 1% AEP event).

The new hydrology was used to re-run the baseline flood models and all options testing models.

3.2 Flooding Mechanisms

The CAFRA model tests a number of joint-probability scenarios, considering pairs of fluvial and tidal events with differing likelihoods which are estimated to provide a desired overall probability of occurrence. These vary from completely fluvial-dominant to completely tidal-dominant events. For all modelled events the critical flood event is shown to be a highly fluvial-dominant event. This generates the greatest flow volume in the Malago when tide-locked and therefore the greatest flood volume and subsequent depth and extent.

The CAFRA model was re-run with the updated Malago hydrology, and the model results for events affecting the study site are shown in Figure 3-1.

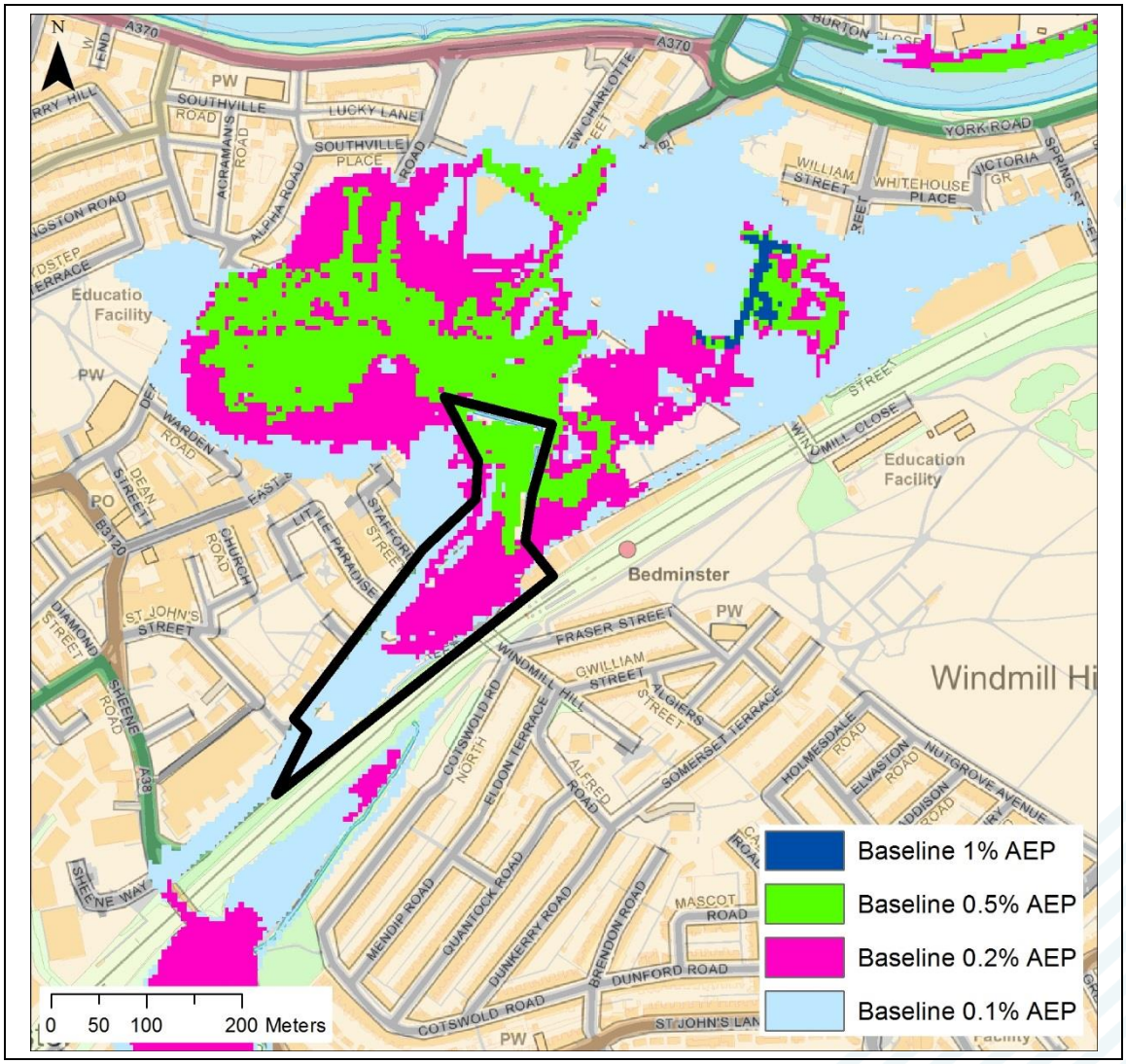


Figure 3-1: Current Day Flood Extents

The model results show that the Bedminster area is at risk of flooding in events larger than the 1% Annual Exceedence Probability (AEP) event. During this 1% AEP event, flooding is fairly limited and is a result of surcharging manholes on the culverted river and flood relief system, as flows are unable to discharge against elevated tidal levels downstream.

In the 0.5% AEP event and above, flooding is predicted from the open channel reaches of the Malago downstream of the Hereford Street culvert, as a result of tide locking from the high levels on the Avon. The depth and extent of flooding in the Bedminster area is therefore driven primarily by the volume of flow in the River Malago channel, rather than by peak fluvial flows and the channel capacity.

In the larger events, flooding occurs from open channel reaches further upstream, as the downstream tidal levels are higher and the downstream outlet is tide-locked earlier and for a longer duration. The open channel reach upstream of Hereford Street is first exceeded in the 0.2% AEP event, flooding part of the land parcel adjacent to the railway, with the remainder of this parcel being flooded in the 0.1% AEP event from flows overtopping the Sheene Road Flood Relief culvert and flowing along Malago Road into the site.

3.3 Economic Impact of Flooding

Internal and external flooding of properties has an economic impact. The majority of financial cost is due to the damage incurred to the property, possessions and vehicles (direct damages) but there are also secondary costs such as the emergency response and emergency accommodation (indirect damages) and the impact to health (intangible damages).

Data on the flood risk to properties was derived from the updated modelled results supplied by Bristol City Council.

JBA's FRISM tool has been used to assess the damages associated with flooding. FRISM is a GIS-based tool developed to analyse flood impact and damages, implementing the Environment Agency's guidance on assessing damages for FCERM schemes and using the Multi-Coloured Manual (2013) to derive financial damages associated with flooding.

Properties are considered as flooded if the water depth exceeds 50mm within the property footprint. This allows for raised property thresholds above surrounding ground level and is considered to be appropriate for the local area based on a review of typical property threshold heights in the vicinity of the site.

A detailed flooded property count was carried out using the Master Map building footprints in conjunction with National Receptor Database (NRD) property points, to remove non-qualifying buildings (i.e. sheds, garages, glasshouses) from the analysis

The Multi-Coloured Manual (MCM) 2013 was used to provide depth-damage curves for the damage calculation. The calculated damages are a combination of direct, indirect and intangible damages. For the purposes of this analysis, the flood damage curve used was "Fluvial, Long duration, No Warning" as it is thought to best represent the likely flood mechanisms in the study area.

FRISM also calculates Present Value Damages which is a measure of the likely total damages over the appraisal period, with future damage discounted to a current day value.

Return Period	Properties at Risk		Estimated Flood Damages
	Residential	Non-Residential	
1% AEP	0	0	£0
0.5% AEP	117	52	£3,786,000
0.2% AEP	299	114	£12,588,000
Present Value Damages (Based on current day results)			£1,802,000

*NOTE: Due to low confidence in 0.1% AEP model results, these have not been included in the FRISM analysis.

Table 3-2: Baseline Damages associated with flooding

4 Options Appraisal

The baseline assessment has demonstrated that the River Malago in the vicinity of the development site has been heavily modified, with the channel being straightened and flood relief structures significantly reducing peak flows. This has led to the shallowing of flows, the homogenisation of the river channel and a general deterioration in the environmental and amenity benefits offered by the river.

Furthermore, development around the river corridor is shown to be at risk of flooding where large fluvial events coincide with high tides.

Therefore, as part of the proposed regeneration there is justification to consider options for works to improve the condition of the river and to provide flood risk benefits to the local area. The options will look to maximise the benefits of the River Malago as an asset to the regeneration site and the wider area.

4.1 Design Criteria

Based on the findings of the baseline assessments, an understanding of the flooding mechanisms and of planning and environmental regulations, it has been possible to develop a list of outline design criteria for consideration during the development of the option long list.

River Restoration Criteria

- Maximise the extent of open channel reach, daylighting culverts where feasible.
- Narrow the existing low-flow channel to create deeper flow of water.
- Increase morphological diversity within the channel, with variations in the depth, width and velocity of flow in the channel.

Flood Mitigation Criteria

- No increase in flood risk to property from the River Malago.
- Increase the volume of storage available within the river channel and floodplain.

Engineering & Development Criteria

- The scheme should not compromise the ability to deliver the redevelopment and should complement the proposed land uses and developments wherever possible.
- Works should not impact on the stability of existing river walls.
- Seek opportunities to improve access to the channel for maintenance of river walls, culverts and other structures.
- Minimise potential for clashes with existing services and utilities.

Environmental Criteria

- Mitigate or prevent any impacts to protected species.
- Minimise the risk of mobilising Invasive Non-native species.
- Seek opportunities to create new terrestrial and aquatic habitats within the River Malago corridor.
- Improve amenity opportunities associated with the river.

4.2 Alignment Options

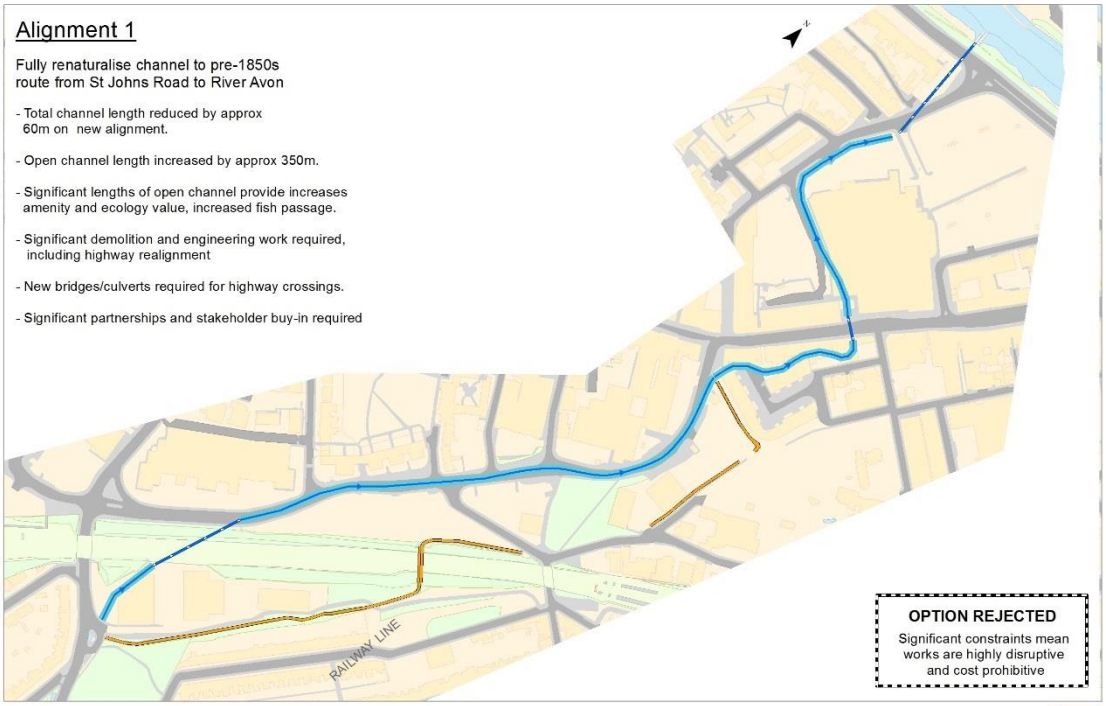
The development of potential options was carried out in two stages. The first stage considers the potential alignment of a restored River Malago channel. Five alignment options were considered, and a discussion of each option is provided below.

4.2.1 Alignment 1: Full Naturalisation to 1750 route

This option would seek to fully renaturalise the River Malago as far as possible, from its crossing beneath the railway to the River Avon.

Prior to its modification after 1750, the course of the River Malago meandered in a broadly northerly direction, from near the current railway crossing to the junction of St Johns Road and Coronation Road. This route passes through existing residential and retail areas including Bedminster High Street and crosses numerous highways.

Implementation of this option would require the demolition of numerous properties and businesses, plus the construction of bridges to cross the watercourse. There would be widescale disruption associated with the construction of this option. The cost of such a scheme would be very significant. This option was rejected on viability grounds.



BEDMINSTER GREEN FLOOD MITIGATION ALIGNMENT OPTIONS - OPTION 1	Drawn By: D Taylor	March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	March 2018	STATUS: FINAL

4.2.2 Alignment 2: Full Naturalisation to pre-1850s route

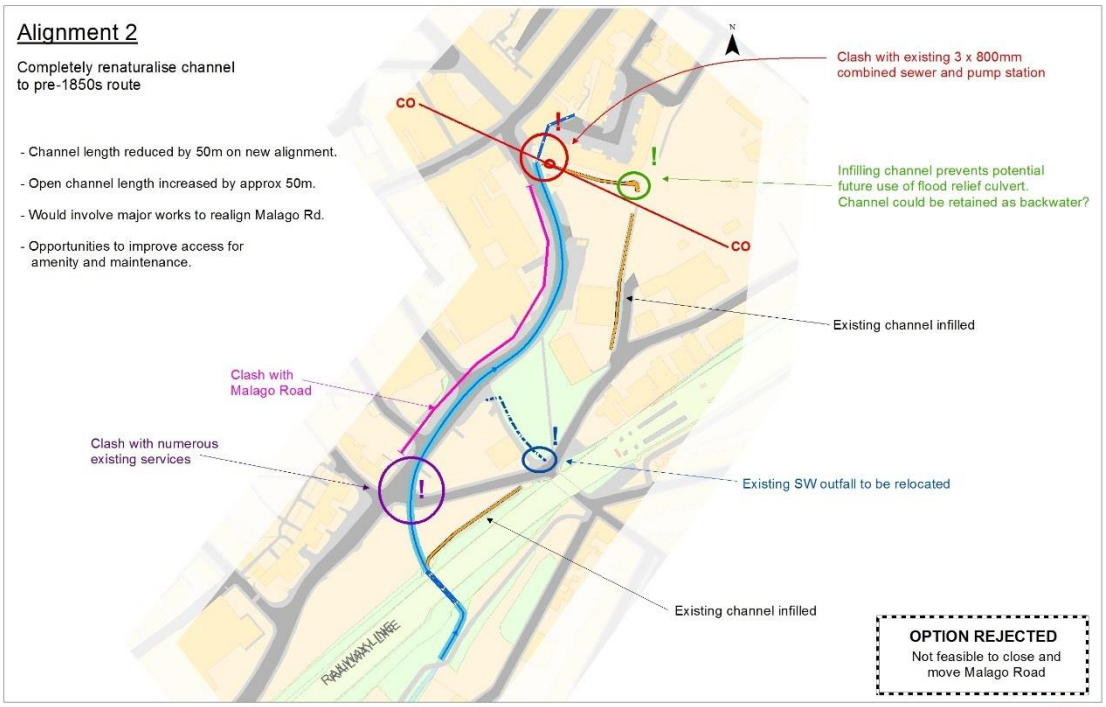
This option would seek to fully renaturalise the River Malago, from its crossing beneath the railway to the culvert at Bartley Street, along its former route.

Prior to its modification, the course of the River Malago was approximately along the line of Malago Road, and so a full naturalisation of the channel would require a diversion of the Malago Road, probably into the plots to the east of the road.

The existing channel would likely be backfilled to create additional development space, to compensate for land lost as a result of the new river course. Existing outfalls and a flood relief culvert (currently abandoned but potentially operable) are served by the existing channel, so it is likely that a new pipe would need to be retained along the route of the existing channel to maintain connectivity with this infrastructure.

Additionally, the route of the channel would lead to conflicts with numerous existing services along the route of Malago Road and Hereford Street and combined sewers and pumping station at the northern extent of the realignment.

As the Malago Road is a major highway into central Bristol, closure of this road for a significant period of time is unlikely to be acceptable. Furthermore, the cost of the new road and service diversions are expected to make this option infeasible. This option was therefore rejected on viability grounds.



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4.2.3 Alignment 3: Naturalisation to near pre-1850s route

This option would seek to renaturalise the River Malago, from its crossing beneath the railway to the culvert at Bartley Street, as close as possible to its former route but avoiding a diversion of Malago Road.

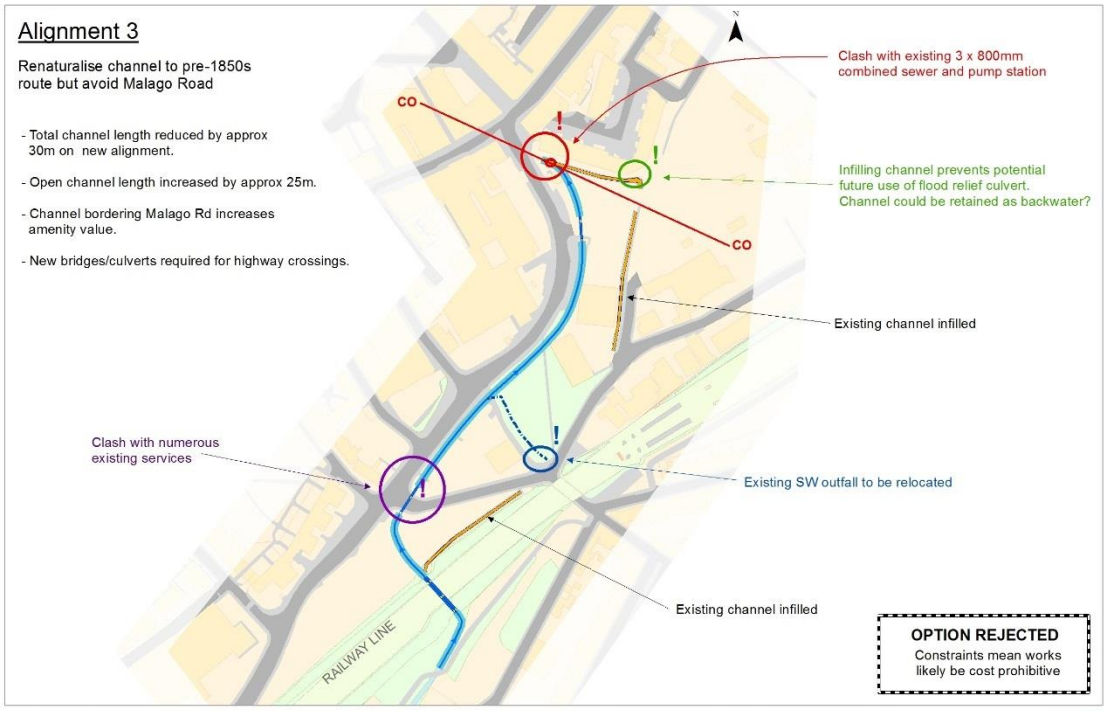
Whilst the historic course of the River Malago was approximately along the line of Malago Road, it is considered that realigning to a location approximately parallel to the highway could still be considered as a naturalisation.

As with the option above, the existing channel would likely be backfilled to create additional development space, to compensate for land lost as a result of the new river course, although consideration must be given to the location of existing outfalls and connectivity with the existing flood relief culvert.

Whilst avoiding the most significant conflict of Malago Road, the potential route of the channel would lead to conflicts with numerous existing services along its lengths, plus combined sewers and pumping station at the northern extent of the realignment.

Access to the new developments would be required from Malago Road, and so new bridges would need to be constructed across the diverted channel.

The cost of the diversion works, plus the new bridges and service diversions, are expected to make this option unfeasible. This option was therefore rejected on viability grounds.



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4.2.4 Alignment 4: Maintain Existing Course, Culvert Daylighting

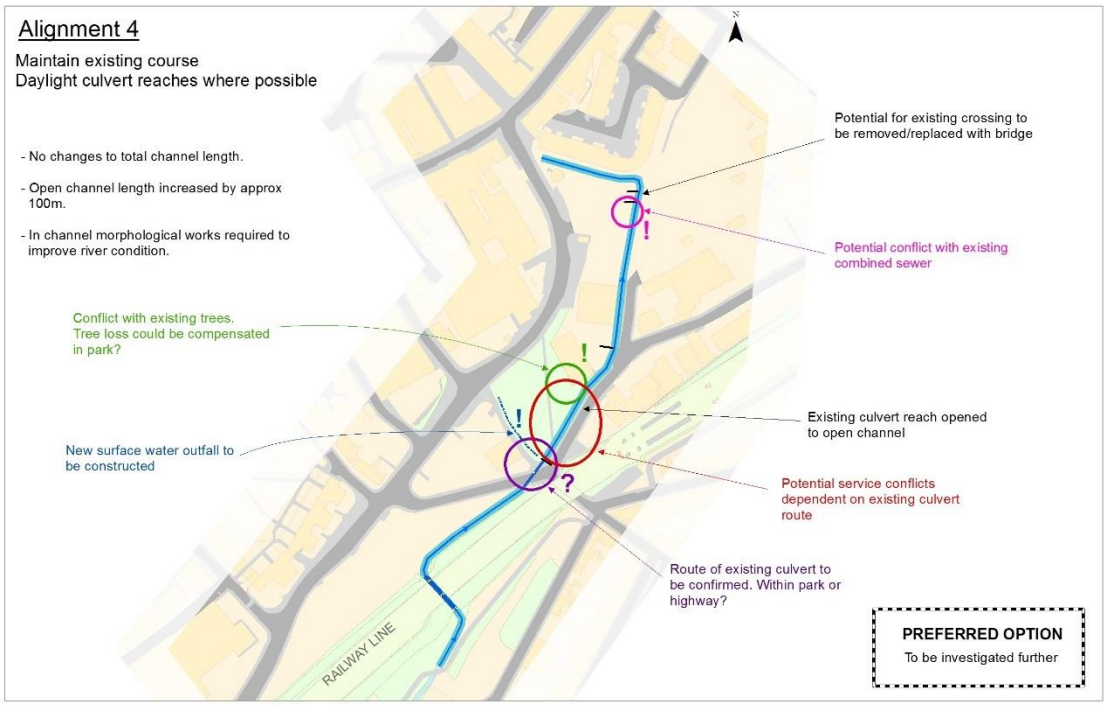
This option would seek to maintain a similar course to the existing channel, but would daylight culverted reaches wherever possible through the site and would also look to naturalise the river within the existing open reaches.

The most significant works would be through the existing park, where approximately 90m of culverted watercourse could be opened. It may also be possible to remove the existing channel crossing in the north-west corner of the site. Opportunities will be sought to naturalise existing open channel reaches by replacing vertical channel walls with slopes, which may lead to an overall widening of the river corridor and by carrying out works within the normal flow channel.

Maintaining a similar alignment to the existing will minimise the risk of clashes with existing services and utilities. However, an existing surface water outfall within the park will need to be modified and there is a risk of clashes in areas with existing culverts. Additionally, existing trees in the eastern corner of the park would need to be removed to create the new channel, although mitigation measures could be implemented by replanting elsewhere within the park.

It is likely that pedestrian access will need to be maintained across the channel into the new development. It is anticipated that this could be readily achieved through the construction of new clear-span pedestrian bridges at or above the top-of-bank-level, without affecting the potential benefits of the scheme.

This option could offer substantial benefits to the river and the development, both in terms of flood risk and environmental improvements with construction costs likely to be proportional to the benefits. Therefore, this is considered to be the preferred option for the scheme.



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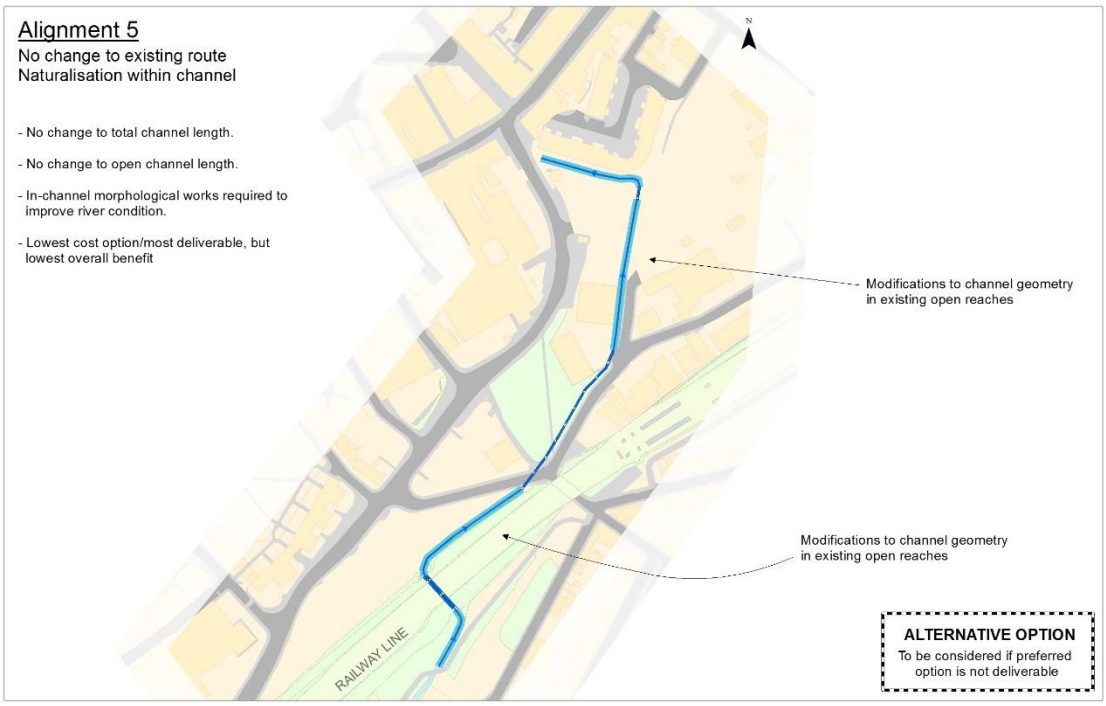
4.2.5 Alignment 5: Maintain existing course, with in-channel works only

This option would seek to maintain the existing channel on its current alignment, with any improvement works being limited to morphological improvements within the existing channel. The proposal is unlikely to generate substantial flood risk benefits, as there will be little change to the hydraulics of the channels during more significant flood events.

This option will have the smallest impact on the proposed development, as there would be no increase in land take associated with the river channel and no change to site access for vehicles or pedestrians.

As the scale and extent of the works will be limited, the potential for clashes with services and utilities, or other significant constraints, is also limited.

This option would be relatively low cost and is considered to be affordable. It will be retained as an alternative. If it is found that the preferred option is not deliverable this one could be delivered either in part or in whole to provide some improvement to the river channel.



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5 Preferred Option

5.1 Description

The preferred option is to maintain a similar channel alignment to the current situation, daylighting culverts wherever possible to maximise the extent of open channels and increase flood storage volume capacity.

The existing park will be landscaped to provide additional floodplain volume, whilst the proposed development plots downstream of this are raised to reduce the predicted depth of flooding. Additionally, works will be carried out to naturalise the channel banks wherever possible by lowering or removing retaining walls and creating vegetated slopes. A new narrower, deeper low-flow channel will be created to improve the geomorphological condition and increase the ecological potential of the channel in this reach. Small modifications will be made to the bypass structure at the Sheene Road flood relief structure, with the opening area being reduced to limit the flow entering the Malago during more extreme flood events.

Plans of the proposal are shown in Appendix A.

5.2 Impact on Flood Risk

The updated CAFRA model has been used to test the impact of the proposal on flood risk during extreme flood events and FRISM was then re-run to test the impact of the scheme on flooding related damages

5.2.1 Impact on Flood Risk

Hydraulic modelling shows that the proposed scheme will provide benefits to downstream property during the 1% AEP and 0.5% AEP flood events, as a result of the additional floodplain volumes and the flow limiting effect at the Sheene Road flood relief culvert bypass. The proposal will not provide any significant improvement to the standard of protection against flooding (i.e. no significant movement from moderate risk to low risk), however this was not a key objective of the scheme.

Although increases in flood depth are observed in the vicinity of the channel, these are expected as they coincide with areas where the channel banks have been lowered and naturalised.

During the 0.1% AEP event, the model predicts some minor detrimental impacts downstream of the site in the vicinity of Princess Street. Given that the impacts are only shown in a location remote from the site, with negligible changes closer to the site, the impact is considered to be a result of a small increase in the volume of flooding from the site ponding in the affected area. It is considered that this impact could be a result of model instabilities, as the increased available floodplain should reduce the volume of flooding. Moreover, the model also predicts significant changes in flood level near Headley Lane / Hartcliffe Way which are sufficiently far upstream not to be affected by works at the site.

Therefore, it is recommended that the model be reviewed and refined as part of detailed design to confirm whether the scheme would generate a detrimental impact.

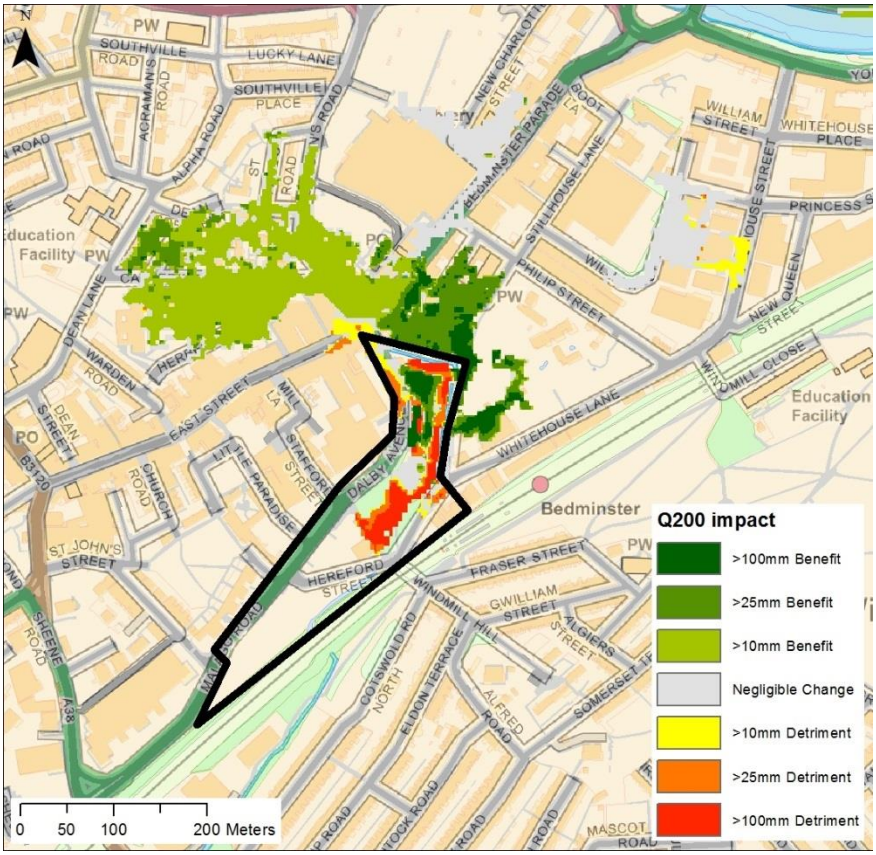


Figure 5-1: Impact of proposals in 0.5% AEP event

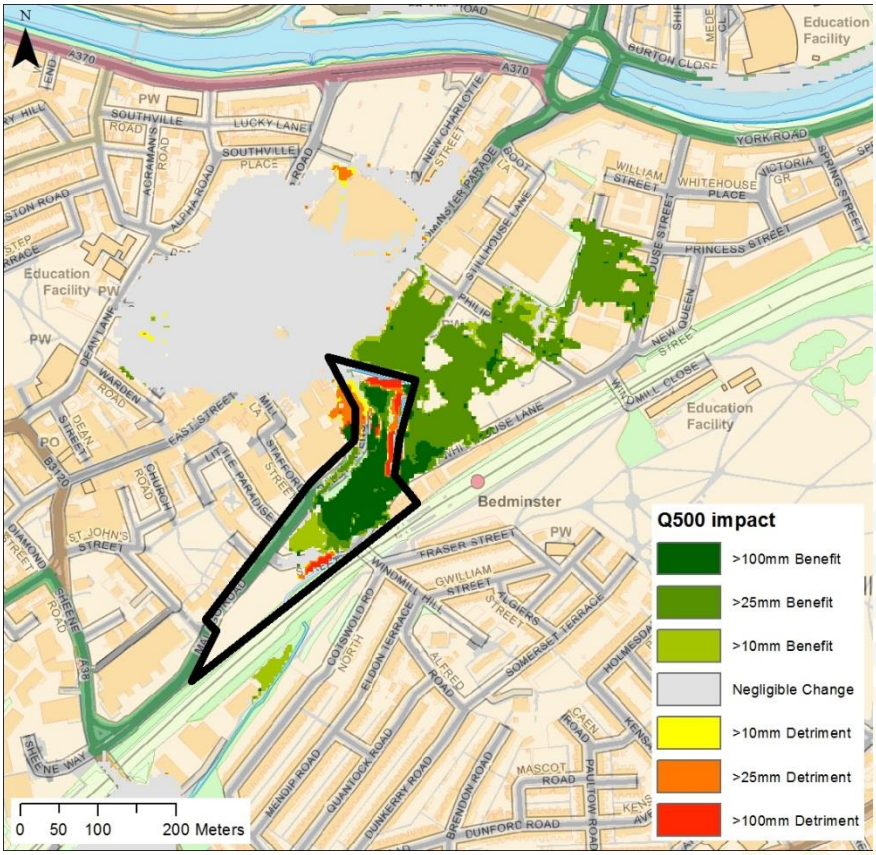


Figure 5-2: Impact of proposals in 0.2% AEP event

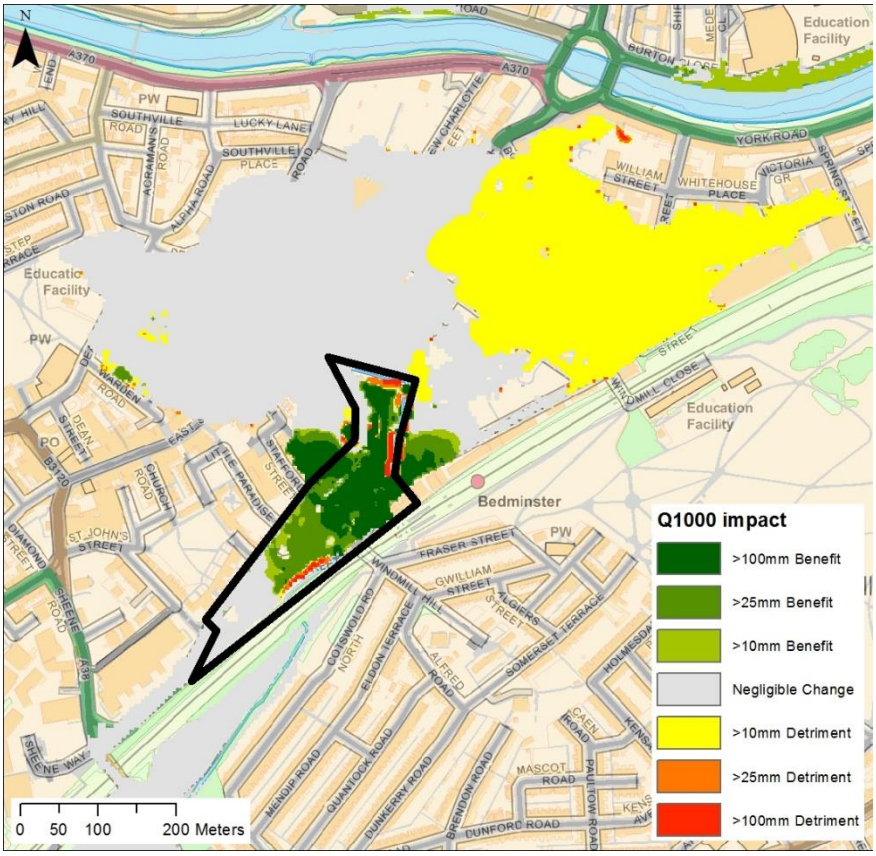


Figure 5-3: Impact of proposals in 0.1% AEP event

5.2.2 Impact of scheme on flood damages

The FRISM analysis was re-run to test the impact of the proposed scheme on flooded property count and financial damages associated with flooding. It can be seen that the proposal will reduce flood risk in the Bedminster area, with up to seventeen properties (residential and non-residential) benefitting from the scheme in the 0.5% AEP event. As flooding to the area is expected to be infrequent, these benefits have a relatively small impact on the Present Value Damages.

Return Period	Properties at Risk		Estimated Flood Damages
	Residential	Non-Residential	
1% AEP	0	0	0
0.5% AEP	116	45	£3,301,000
0.2% AEP	297	114	£11,666,000
Present Value Damages (Based on current day results)			£1,647,000

*NOTE: Due to low confidence in 0.1% AEP model results, these have not been included in the FRISM analysis.

Table 5-1: FRISM results for the proposed scheme

Return Period	Properties at Risk		Estimated Flood Damages
	Residential	Non-Residential	
1 in 100-year	0	0	0
1 in 200-year	-1	-16	£485,000
1 in 500-year	-2	-11	£922,000
Present Value Damages (Based on current day results)			£155,000

Table 5-2: FRISM results showing impact of river restoration scheme

5.3 Potential Environmental Impacts

The proposed scheme will create approximately 100 metres of new open channel, 100 metres of new naturalised banks and bed and 200 metres of improved bed and partially naturalised banks. This provides a total of approximately 400 metres of channel improvements.

Narrowing of the low flow channel will increase both the depth and velocity of flow, providing improved habitat for fish by reducing water temperatures and increasing oxygen in the water. Increased flow velocity will reduce the ability for very fine sediments to be deposited within the reach, which could improve the suitability of the bed for fish spawning and as a habitat for aquatic invertebrates.

In addition to improving the environmental condition of the river itself, the proposed works are intended to enhance the aesthetic of the channel and provide greater amenity benefits for the new development and the wider community. The naturalisation of the slopes and planting of aquatic and terrestrial vegetation are expected to provide a positive visual impact and to increase public connectivity with the river, currently hidden and not publicly accessible.

The proposed works will require the removal of some trees within the park and adjacent to the existing commercial buildings on Hereford Street. A Preliminary Ecological Assessment of the channel through the scheme site was carried out and it was concluded that none of these trees are likely to provide suitable habitats for protected species. However, it is recommended to mitigate this loss by planting new trees within the local area. It is considered that both the existing park and the new development provide suitable opportunities for compensatory tree planting.

During the Preliminary Ecological Appraisal walkover, Invasive Non-native Species (INNS) including Himalayan Balsam and Japanese Knotweed were observed on the banks of the channel. The Japanese Knotweed currently appears to be in one isolated location but the Himalayan Balsam is widespread. Constructions works will need to include measures to prevent the spread of these INNS.

5.4 Outline Scheme Costs and Funding

Estimates of the scheme capital costs have been produced to support future discussions with landowners, developers and potential project funders. It should be noted that these are outline costs only and that detailed costs should be estimated by a competent contractor with access to detailed site surveys, including ecology, ground investigation and detailed underground services survey. These outline costs are based on unit costs derived from the Environment Agency's Costing Guides for Channel Management and Fluvial Defences.

A full breakdown of the outline costs and assumptions is included in Appendix B and Table 5-3 provides a summary of the total cost estimates. Due to the different nature of the channel works in each reach and the potential for delivery of the works to be phased if completed by the plot developers, costs have been calculated separately for works at each of the proposed development plots.

Works Location	Cost Estimate
Plot 001	£184,000
Plot 005	£310,000
Plot 003	£212,000
Total	**£706,000**

Table 5-3: Outline Scheme Costs (CAPEX)

It can be seen that the estimated total scheme costs are significantly greater than the calculated flood risk benefits and so the scheme could not be justified on flood risk benefits alone. However, the proposal will generate multiple benefits such as increased biodiversity and land and property value through improved visual appeal which, whilst not quantifiable at this stage, help to justify the viability of the scheme.

At this stage, the funding mechanism for the proposal is unclear, however it is likely that some form of partnership funding will be required to deliver it. The following groups could form part of any project delivery partnership and aid in the provision of funding or contributions in kind:

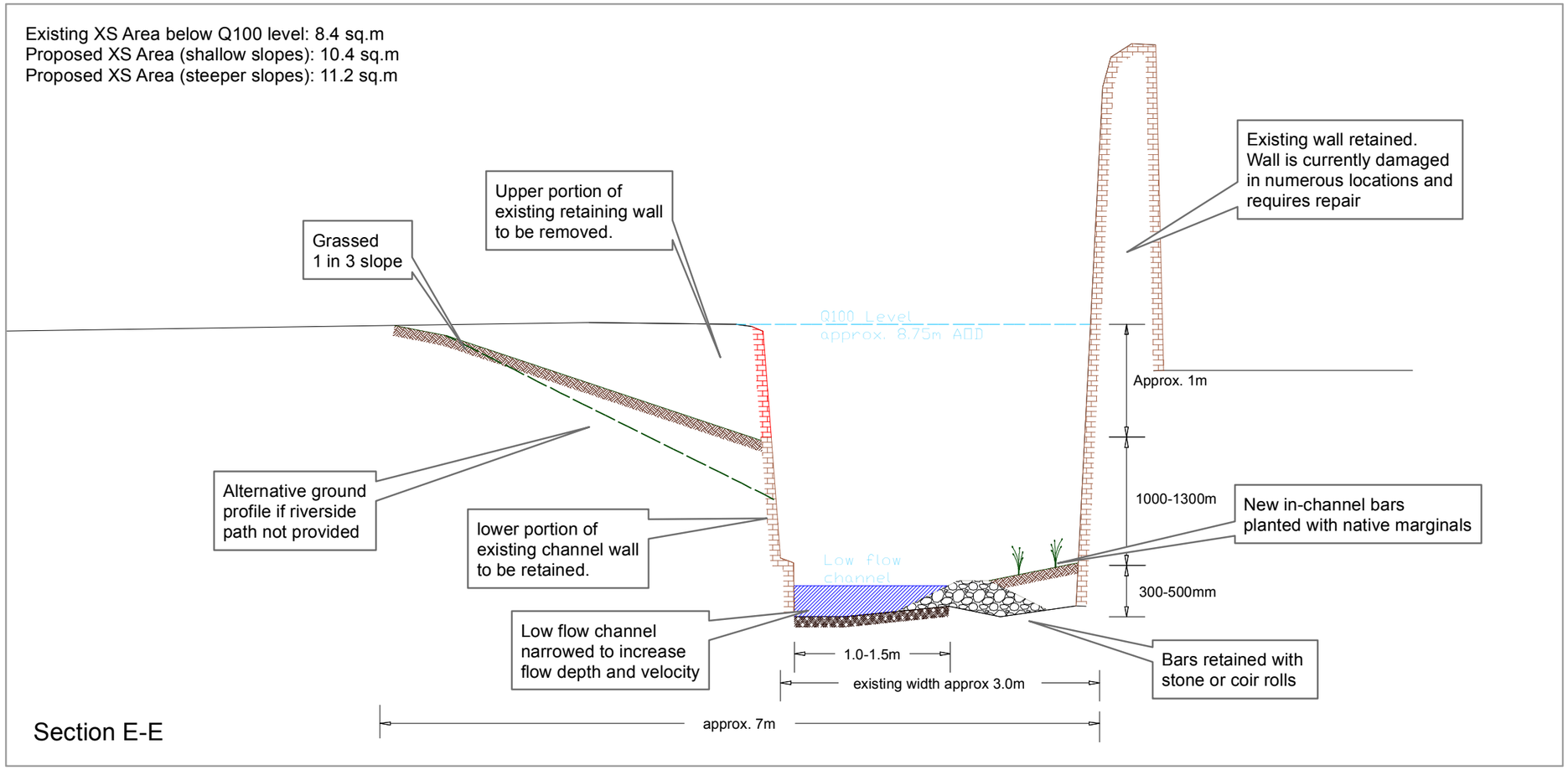
- Direct contribution from developers of the adjacent site, as part of their site landscaping works
- Bristol City Council
- Environment Agency
- Natural England
- Bristol Avon Rivers Trust
- Avon Wildlife Trust
- Other local interest groups & Community groups

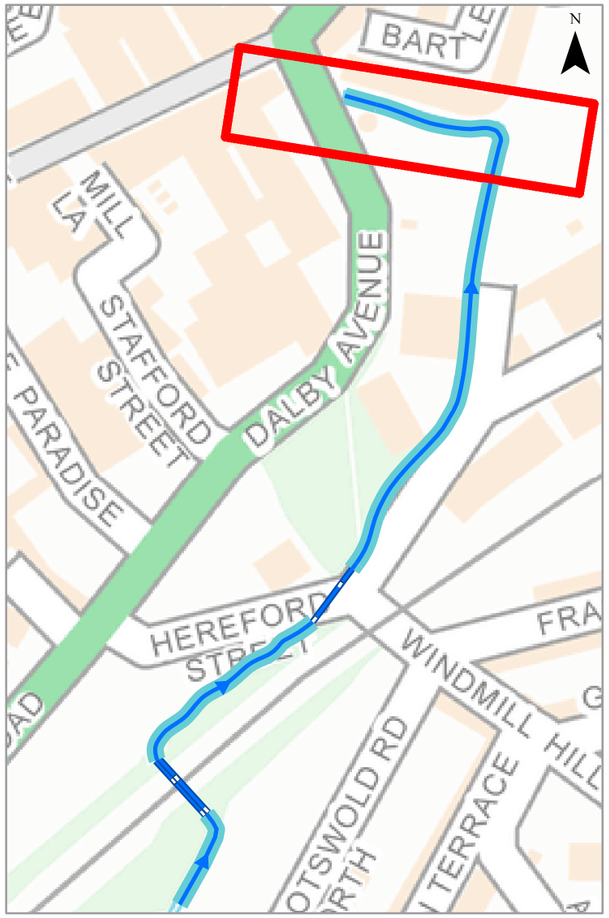
6 Conclusion & Recommendations

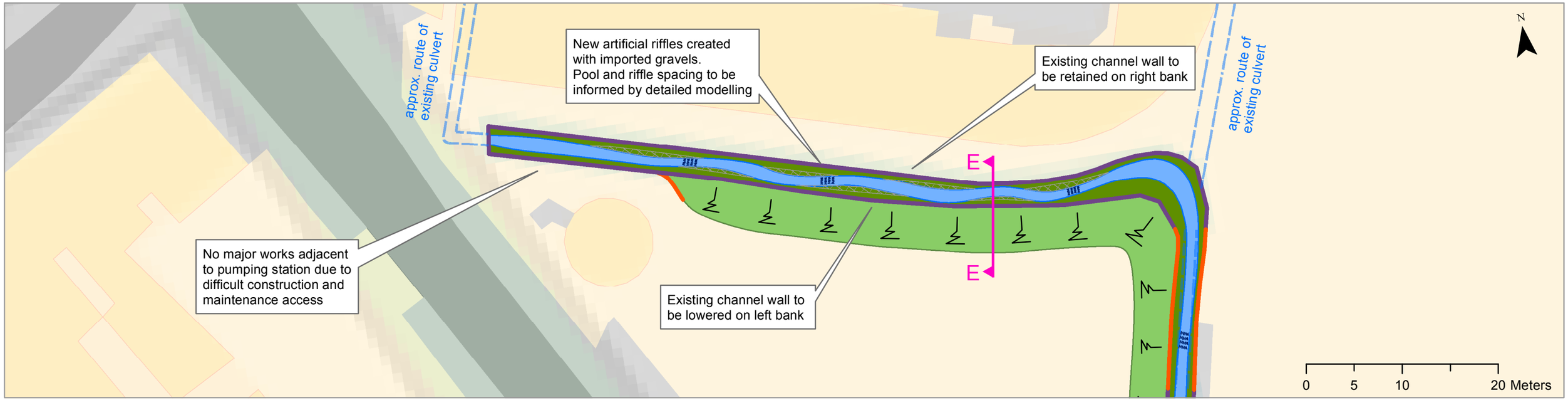
- JBA was commissioned by Bristol City Council to assess potential river restoration options for a reach of the River Malago in Bedminster, as part of the wider Bedminster Green regeneration scheme.
- Several objectives were set for the study:
  - Carry out a baseline assessment of flood risk from the River Malago and assess the current morphological condition of the river in the vicinity of the site.
  - Develop and appraise options to improve the condition of the River Malago and provide flood risk reduction benefits.
  - Select a preferred option and assess the potential benefits of this option including economic analysis.
- Baseline flood modelling was carried out using the existing CAFRA hydraulic model, but with updated hydrology for the River Malago and Pigeonhouse Stream.
- Baseline modelling shows that the regeneration site is a t risk of flooding in the 0.5% AEP flood event and higher, with the primary cause of flooding being exceedence of channel banks during tide-locking scenarios
- The River Malago was found to be in poor morphological condition in the study reach, caused by historic hydrological and morphological changes leading to shallow flows, low flow velocities and fine sediment deposition. The channel exhibits very low morphological diversity.
- Five potential river restoration approaches and alignments were initially considered and three of these were rejected on viability grounds. Both remaining options retained the channel on its current course, with differing scales of works carried out to the channel itself.
- A preferred option was then developed, which sought to maximise the environmental and flood risk benefits of the scheme, through naturalisation of the banks, in-channel works to improve morphology and daylighting of culverts where possible.
- The preferred option was modelled using the CAFRA model and was shown to offer flood risk benefits during the 0.5% AEP and 0.2% AEP event, although some detrimental impacts are predicted in the 0.1% AEP event.
- The proposal will not provide any significant improvement to the standard of protection against flooding for local properties (i.e. few properties will move from medium to low risk bands)
- An economic assessment of the flood damages estimated that up to 17 properties could benefit from flood risk reductions and the total benefit of the scheme would be around £155k.
- The capital costs of the preferred option were estimated at approximately £706k. This is an outline cost only and should be reviewed by a competent contractor with reference to additional data and survey.

Appendices

A Preferred Option Drawings



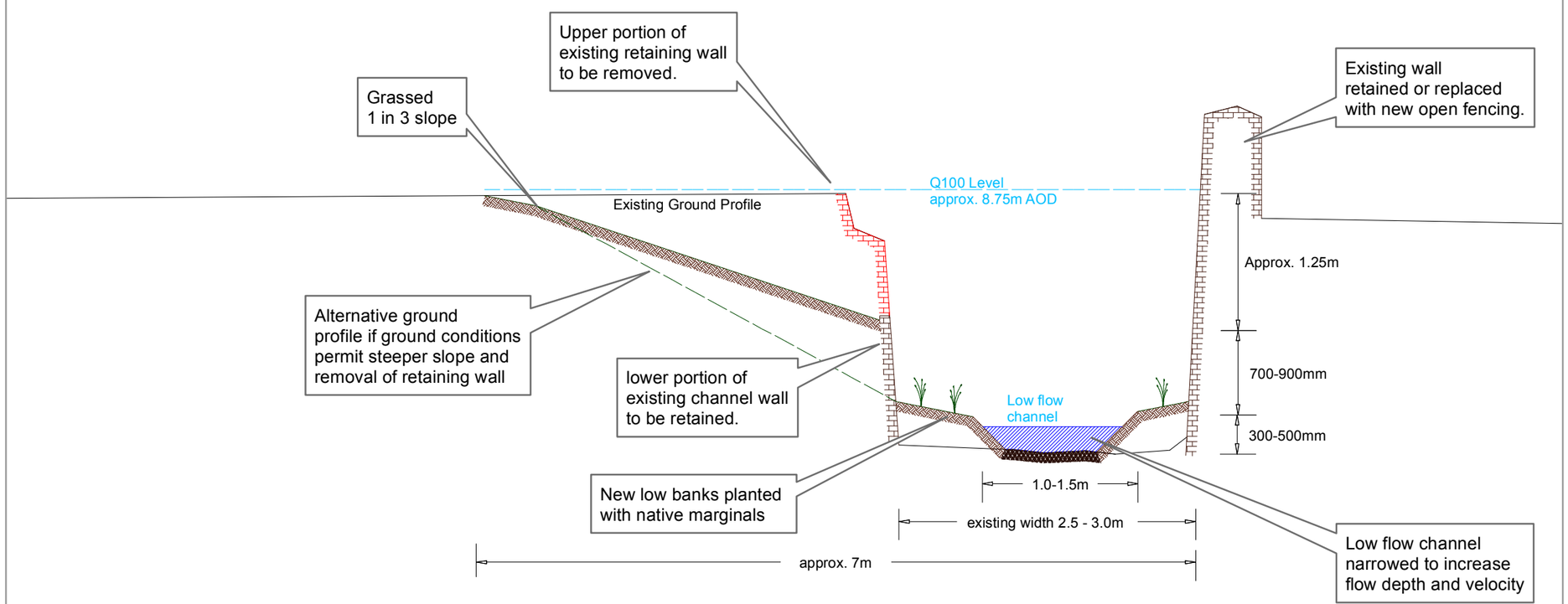




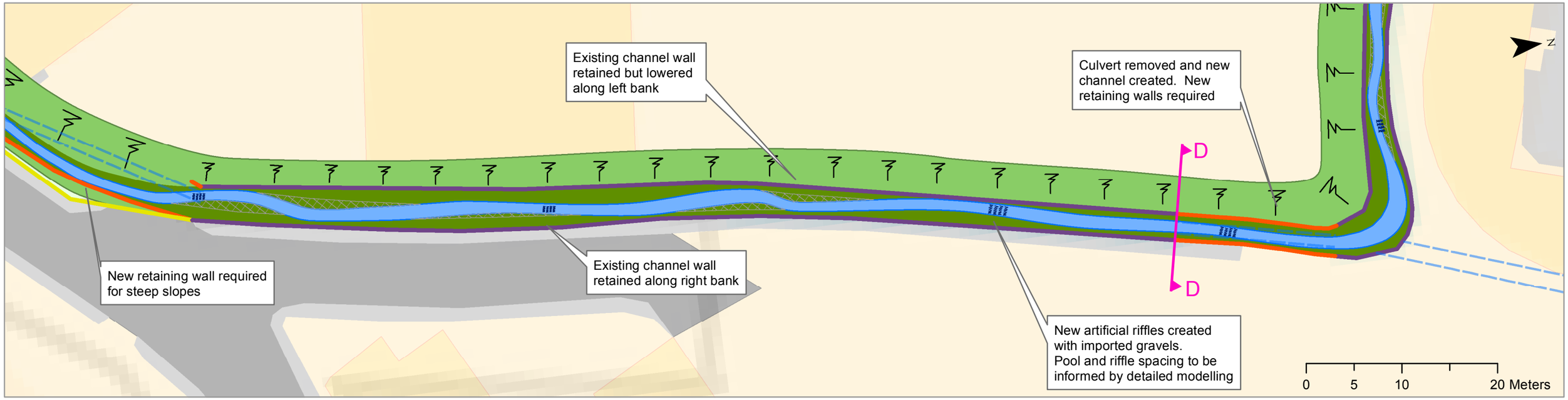
BEDMINSTER GREEN FLOOD MITIGATION PREFERRED OPTION - SHEET 5 CONCEPT SKETCH	Drawn By: D Taylor	27 March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	27 March 2018	STATUS: DRAFT

JBA consulting

Existing XS Area below Q100 level: 7.2 sq.m
Proposed XS Area with wall: 9.4 sq.m
Proposed XS Area with slope: 10.6 sq.m

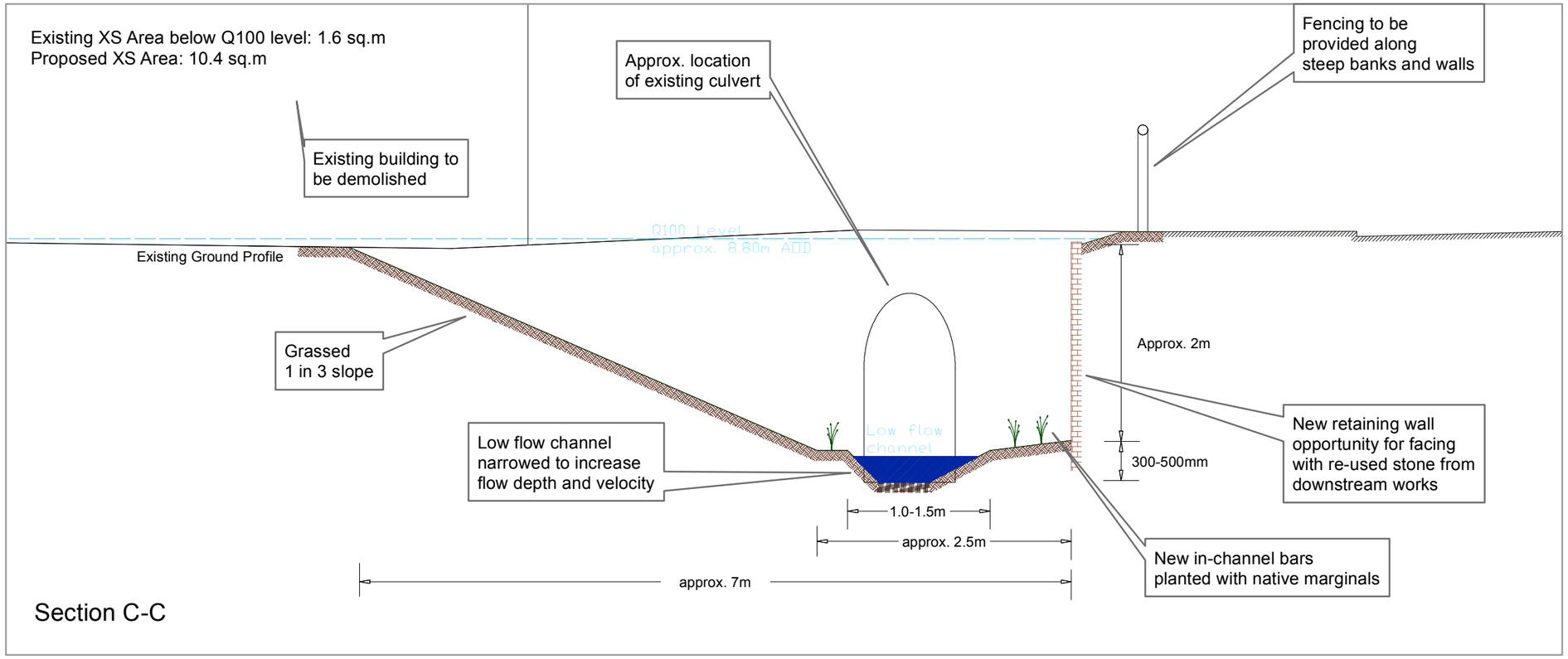


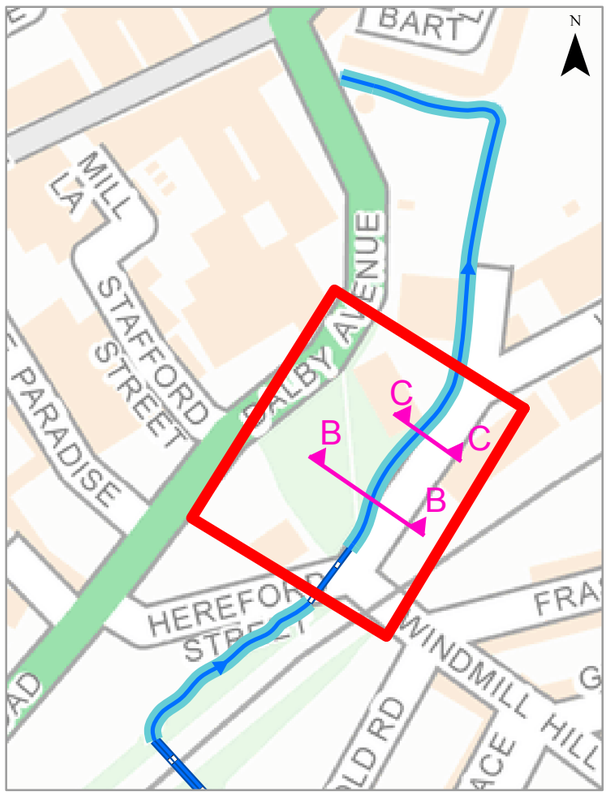
Section D-D

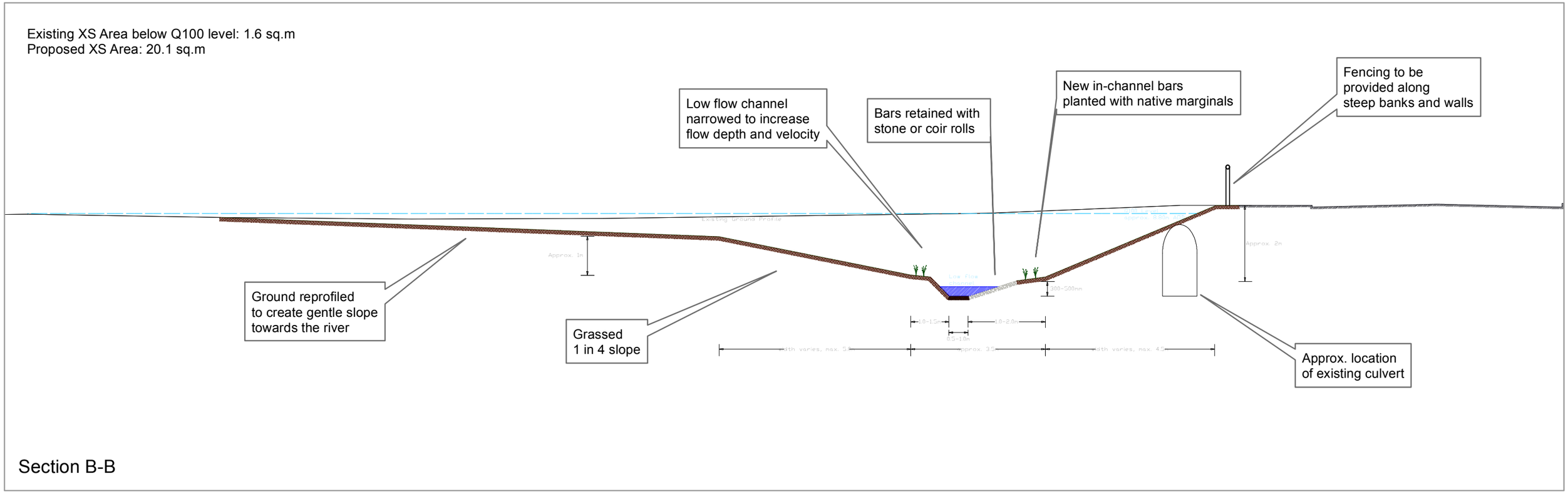


BEDMINSTER GREEN FLOOD MITIGATION PREFERRED OPTION - SHEET 4 CONCEPT SKETCH	Drawn By: D Taylor	27 March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	27 March 2018	STATUS: DRAFT

JBA consulting

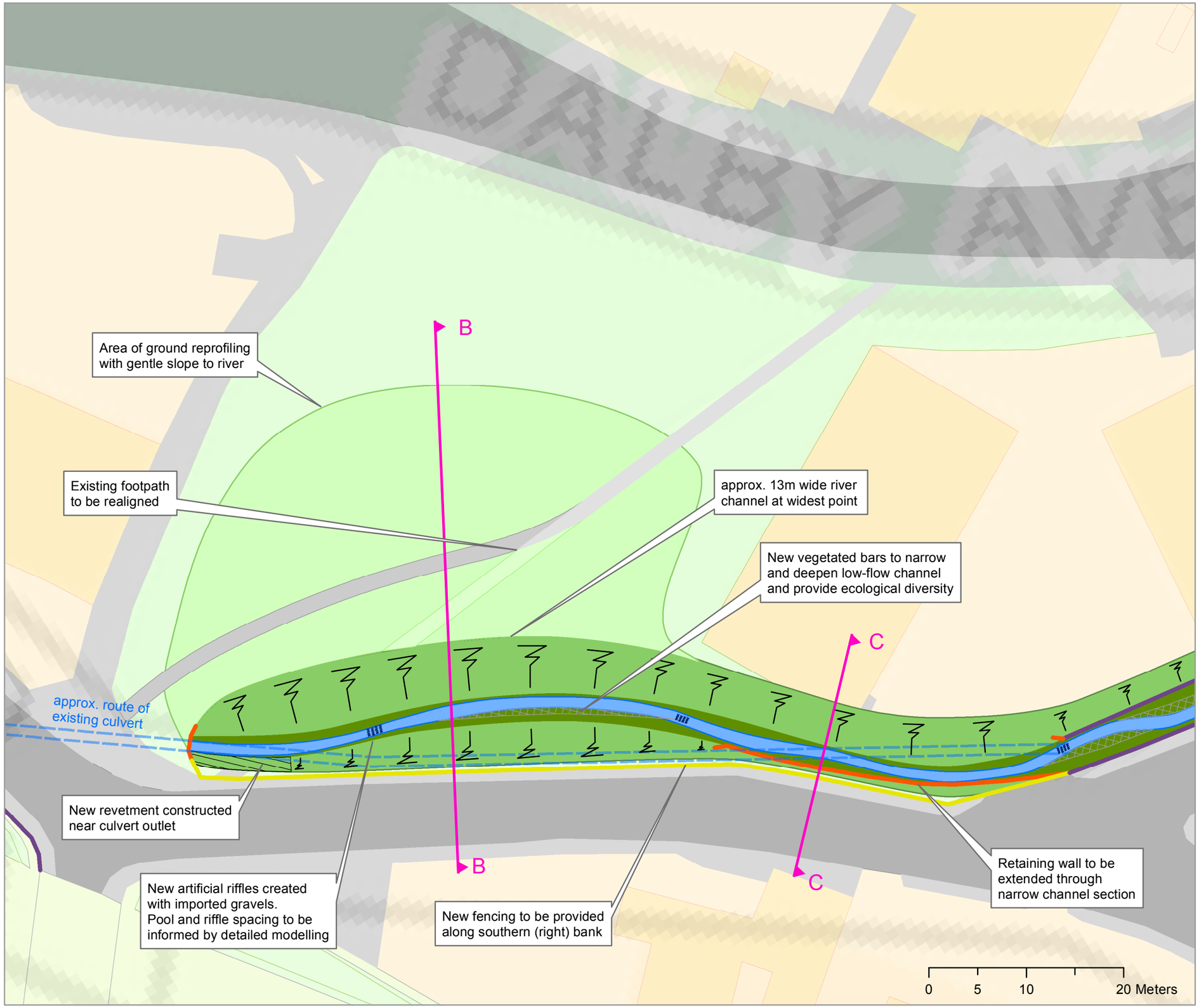






BEDMINSTER GREEN FLOOD MITIGATION PREFERRED OPTION - SHEET 3 CONCEPT SKETCH	Drawn By: D Taylor	27 March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	27 March 2018	STATUS: DRAFT

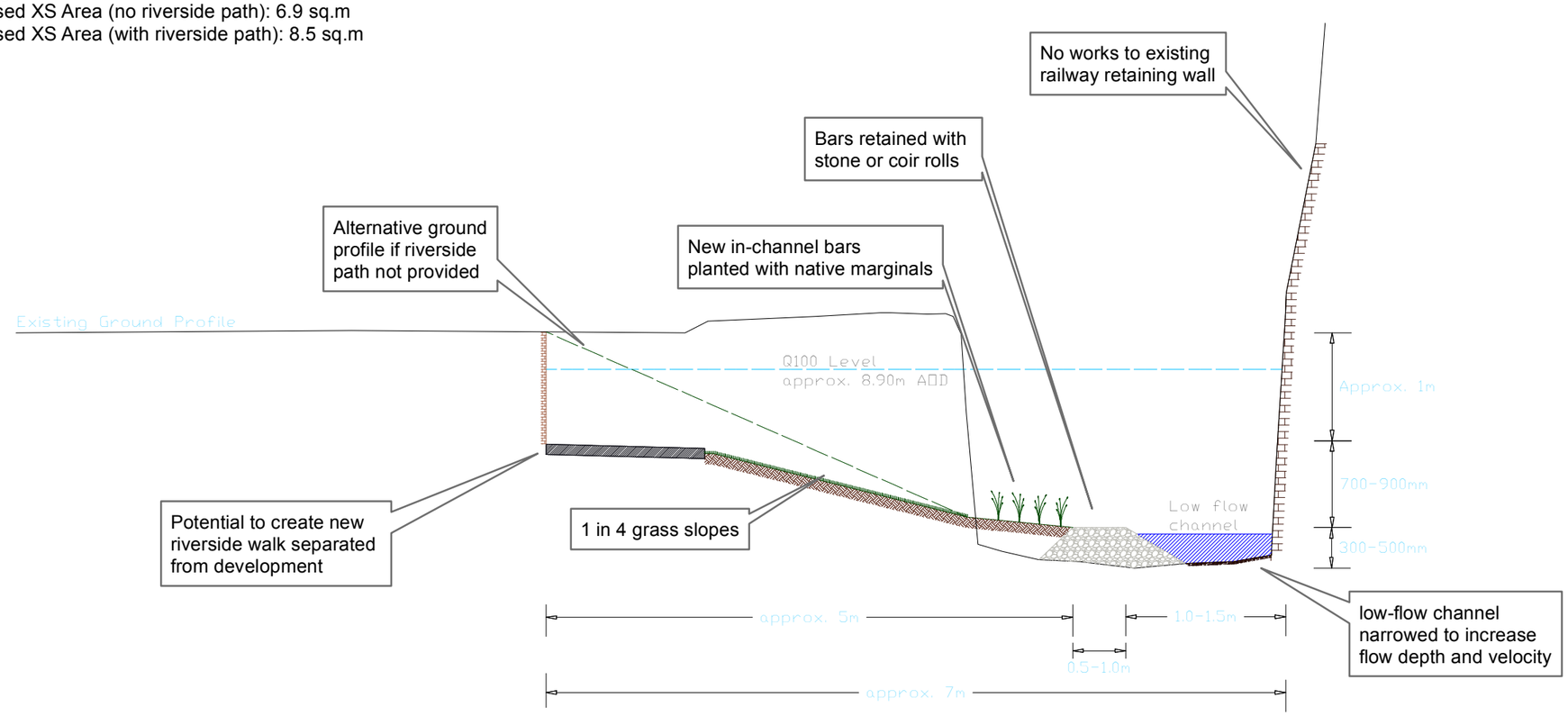
JBA consulting



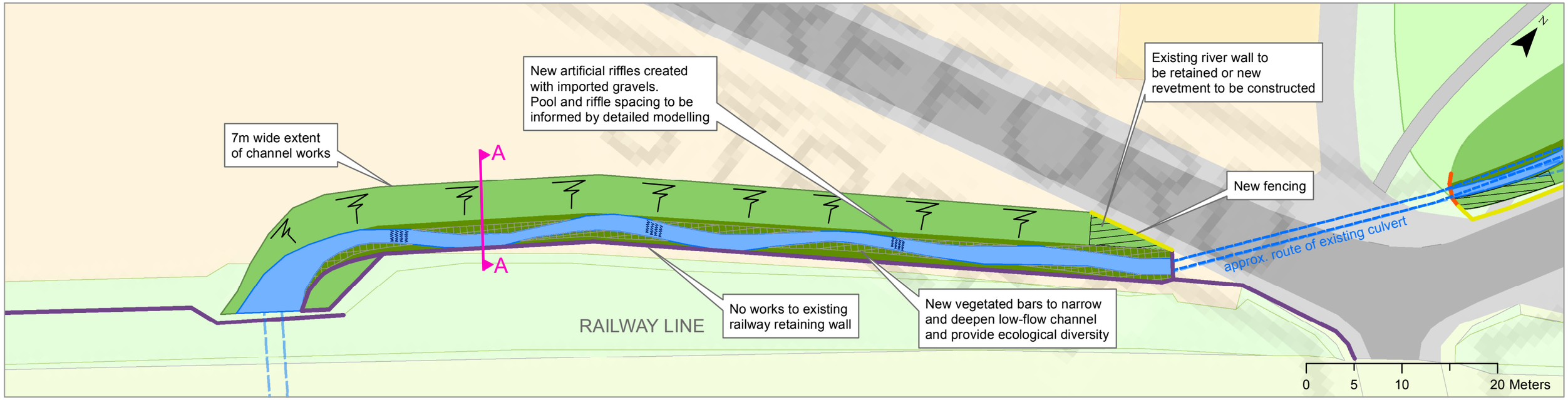
BEDMINSTER GREEN FLOOD MITIGATION PREFERRED OPTION - SHEET 2 CONCEPT SKETCH	Drawn By: D Taylor	27 March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	27 March 2018	STATUS: DRAFT

JBA consulting

Existing XS Area below Q100 level: 5.2 sq.m
Proposed XS Area (no riverside path): 6.9 sq.m
Proposed XS Area (with riverside path): 8.5 sq.m



Section A-A



BEDMINSTER GREEN FLOOD MITIGATION PREFERRED OPTION - SHEET 1 CONCEPT SKETCH	Drawn By: D Taylor	27 March 2018	REV: ORIGINAL
	Checked By: M Hemsworth	27 March 2018	STATUS: DRAFT

JBA consulting

B Outline Scheme Costs

Project name:	Bedminster Green Framework FRA
Project number:	2017s6841
File Description:	Proposed Works - Capital Costs
Client:	Bristol City Council
Produced	Jonathan King
Checked	Tom Wharf
Reviewed/Approved	Daryl Taylor

	File links			
Drawing	Plan PDF		CAD Dwg.	
A-A	Sheet 1		A-A	
B-B / C-C	Sheet 2	Sheet 3	B-B	C-C
D-D / E-E	Sheet 4	Sheet 5	D-D	E-E

Total Cost	£ 706,000	*EA Long Term Costing Documents*
		Cost_estimation_for_channel_management.pdf
Key		Cost_estimation_for_fluvial_defences.pdf
Option - not used		
Uncertain on cost estimate		

			Number of units / Cost																	
			Plot 001				Plot 005						Plot 003							
Item	*Unit*	*£ / unit*	*Units / Dwg. A-A*	*Dimension 1*	*Dimension 2*	*£*	*Units / Dwg. B-B / C-C*	*Dimension 1 / B-B*	*Dimension 2 / B-B*	*Dimension 1 / C-C*	*Dimension 2 / C-C*	*£*	*Units / Dwg. D-D / E-E*	*Dimension 1 / D-D*	*Dimension 2 / D-D*	*Dimension 1 / E-E*	*Dimension 2 / E-E*	*£*	*Total Cost*	*Notes*
Demolition & Site Clearance																				
General clearance				Width (m)	Length (m)			Width (m)	Length (m)	Width (m) / C-C	Length (m) / C-C			Width (m) / D-D	Length (m) / D-D	Width (m) / E-E	Length (m) / E-E			
Clear site vegeration - generally	ha	£ 3,150.00	0.081	9	90	£ 255	0.24	40	52	8	42	£ 761	0.13	8	115	8	47	£ 408	£ 1,424	Site preparation before excavation, unsure of existing site condition, included trees under 500mm - cost tripled due to poor access and small area
Trees	nr	£ 160.00	-	-	-	£ -	20	-	-	-	-	£ 3,200	-	-	-	-	-	£ -	£ 3,200	Girth, 500 mm - 1 m, £40 based on min. 100 tree +- £40 additional cost for stum removal: Total £80 - cost doubled due to small number of trees
Buildings	m3	£ 11.19	-	-	-	£ -	630	-	-	18	35	£ 7,050	-	-	-	-	-	£ -	£ 7,050	Brickwork with concrete floor and roof - assuming room to work around, "non-urban" rate used
Excavation																				
General Excavation				Area (m2)	Length (m)			Area (m2) / B-B	Length (m) / B-B	Area (m2) / C-C	Length (m) / C-C			Area (m2) / D-D	Length (m) / D-D	Area (m2) / E-E	Length (m) / E-E			
General : ne 0.25m max depth	m3	£ 2.58	-	-	-	£ -	-	-	-	-	-	£ -	-	-	-	-	-	£ -	£ -	Excavate material other than topsoil, rock or artificial material
General: 0.25-0.5m max depth	m3	£ 2.61	212.5	2.5	85	£ 551	467.4	6	52	3.7	42	£ 1,213	199.1	1.2	115	1.3	47	£ 520	£ 2,284	Ditto - Total volume 0 - 0.5 m, average all costs
General: 0.5-1m max depth	m3	£ 3.41	161.5	1.9	85	£ 551	563.6	8.9	52	2.4	42	£ 1,922	240.4	1.6	115	1.2	47	£ 820	£ 3,292	Note - includes area ocupied by existing culvert, therefore actual volumes reduced
General: 1-2m max depth	m3	£ 5.16	68	0.8	85	£ 351	401.2	4	52	4.6	42	£ 2,070	-	-	-	-	-	£ -	£ 2,421	
General: 2-5m max depth	m3	£ 8.57	-	-	-	£ -	28.2	0.3	52	0.3	42	£ 242	-	-	-	-	-	£ -	£ 242	
Culvert removal	m3	£ 54.46	-	-	-	£ -	34.78	0.37	52	0.37	42	£ 1,894	6.9	0.37	16	0.37	2.6	£ 375	£ 2,269	Excavate unreinforced concrete not exposed at the commencing surface ne 0.25m maximum depth - if historic culvert then is probably brick and therefore easier / cheaper to remove (see cost to excavate rock, below)
Retaining wall removal	m3	£ 25.98	-	-	-	£ -	-	-	-	-	-	£ -	38.9	0.24	115	0.24	47	£ 1,010	£ 1,010	Excavate rock (medium hard), ne 0.25m maximum depth, assume double skin brick wall
Hardstanding (e.g. tarmac / path, carpark)	m3	£ 25.98	-	-	-	£ -	12.375	0.23	55	-	-	£ 322	20.16	1.20	16.8	-	-	£ 524	£ 845	Excavate rock (medium hard), ne 0.25m maximum depth, assume 150mm depth
Excavation Ancillaries - waste disposal																				
General	m3	£ 18.63	442	-	-	£ 8,234	1432.2	-	-	-	-	£ 26,682	439.5	-	-	-	-	£ 8,188	£ 43,104	Excavated earth other than rock or excavated hard material, removal; 15 km distance; using 20t tipper
Hard material	m3	£ 19.48	0	-	-	£ -	34.78	-	-	-	-	£ 678	45.8	-	-	-	-	£ 891	£ 1,569	Disposal of excavated rock or hard material, removal; 15 km distance; using 20t tipper
Landfill tax - higher rate	m3	£ 88.95				£ -						£ -	485.3					£ 43,164	£ 43,164	Site of former smelting works and tannery - assume hazardous, therefore higher rate landfill tax
Landfill tax - lower rate	m3	£ 2.80	442			£ 1,238	1466.98					£ 4,108	0.0					£ -	£ 5,345	
Landscaping				Width (m)	Length (m)			Width (m) / B-B	Length (m) / B-B	Width (m) / C-C	Length (m) / C-C			Width (m) / D-D	Length (m) / D-D	Width (m) / E-E	Length (m) / E-E			
Preparatory operations	100m2	£ 6.34	2.21	2.6	85	£ 14	14.164	23.2	52	5	42	£ 90	5.994	3.7	115	3.7	47	£ 38	£ 142	Supply and apply granular cultivation treatents by machine (in suitable economically large areas)
Hydraulic mulch grass seeding	m2	£ 1.83	221	2.6	85	£ 404	1416.4	23.2	52	5	42	£ 2,592	599.4	3.7	115	3.7	47	£ 1,097	£ 4,093	10-45 deg to horizontal
Coir rolls	m	£ 70.50	90	-	90	£ 6,345	94	-	52	-	42	£ 6,627	162	-	115	3.7	47	£ 11,421	£ 24,393	Coir rolls (planted with suitable vegetation)
Vegetated bars	m2	£ 150.00	81	0.9	90	£ 12,150	103.5	0.9	52	1.35	42	£ 15,525	197.6	1.35	115	0.9	47	£ 29,633	£ 57,308	Grass and reed planting
Geotextiles; scour and erosion protection	m2	£ 7.42	221	2.6	85	£ 1,640	1416.4	23.2	52	5	42	£ 10,510	-	-	-	-	-	£ -	£ 12,150	For use where hydraulic action exists, 10-45deg to the horizontal
Log toe and geotextile revetment	m2	£ 146.00	10.4	2.6	8	£ 1,518	25	2.5	10	-	-	£ 3,650	-	-	-	-	-	£ -	£ 5,168	Assume existing river wall to be maintained
Filling				Area (m2)	Length (m)			Area (m2) / B-B	Length (m) / B-B	Area (m2) / C-C	Length (m) / C-C			Area (m2) / D-D	Length (m) / D-D	Area (m2) / E-E	Length (m) / E-E			
Imported rock - general (gravel)	m3	£ 56.02	9	1	9	£ 504	3	1	1	1	2	£ 168	7.0	1	4	1	3	£ 392	£ 1,064	Gravel: For use in pool-riffle arrangement - number of riffles to be deterimed by detailed modelling
Brickwork, Blockwork and Masonry				Height (m)	Length (m)			Height (m) / B-B	Length (m) / B-B	Height (m) / C-C	Length (m) / C-C			Height (m) / D-D	Length (m) / D-D	Height (m) / E-E	Length (m)/ E-E			
Retaining wall	m2	£ 576.00	85	1	85	£ 48,960	88	2	2	2	42	£ 50,688	-	-	-	-	-	£ -	£ 99,648	Height band < 1.2 m, 20th percentile cost
Repair to existing retaining wall	m2	£ 200.00	-	-	-	£ -	-	-	-	-	-	£ -	?	?	?	?	?	?		allow £200/m2
Roads and Pavings																				
Light duty pavements				Width (m)	Length (m)			Width (m) / B-B	Length (m) / B-B	Width (m) / C-C	Length (m) / C-C			Width (m) / D-D	Length (m) / D-D	Width (m) / E-E	Length (m) / E-E			Footpath realignment and riverside walkway
Subbase	m2	£ 3.75	127.5	1.5	85	£ 478	99	1.5	66	-	-	£ 371	-	-	-	-	-	£ -	£ 849	100mm thick gravel
Bitumen macadam surfacing	m2	£ 15.89	127.5	1.5	85	£ 2,026	99	1.5	66	-	-	£ 1,573	-	-	-	-	-	£ -	£ 3,599	sloping not exceeding 10deg to the horizontal
Fencing	m	£ 21.57	9.5	-	9.5	£ 205	95	-	53	-	42	£ 2,049	-	-	-	-	-	£ -	£ 2,254	Timber rail fencing, 1.4 m high, timber posts and four rails
Water management																				
Dewatering and water management						£ 5,000						£ 5,000						£ 5,000	£ 15,000	Provisional Sum - assumes 3-phase AC connection.
Overpumping						£ 15,000						£ 15,000						£ 15,000	£ 45,000	Provisional Sums
Modification to upstream diversion structure to throttle normal flow to 0.25 cumec																		£ 5,000	£ 5,000	Unit cost - provisional sum
SUBTOTAL						**£ 85,425**						**£ 143,983**						**£ 98,480**	**£ 327,888**	
Detailled design	10%					£ 8,543		£ -	£ -	£ -	£ -	£ 14,398		£ -	£ -	£ -	£ -	£ 9,848	£ 32,789	
Contractor's Preliminaries	10%					£ 8,543						£ 14,398						£ 9,848	£ 32,789	
Site set up, welfare, fencing, mobilisation and security	20%					£ 17,085						£ 28,797						£ 19,696	£ 65,578	
Risk allowance	15%					£ 12,814						£ 21,597						£ 14,772	£ 49,183	
Optimism Bias	60%					£ 51,255						£ 86,390						£ 59,088	£ 196,733	
Exclusions Services/utility diversions Surveys Ecology (birds, terrestrial and aquatic) impacts, and mitigations Protected/invasive species Contaminated land (extra over assumptions above) Traffic and pedestrian management Flooding risks Tree works Consents, permits, premissions and licencing Consultation and stakeholder engagement																				
TOTAL ESTIMATED COST (+30%/-20%)						A-A						B-B,C-C						D-D,E-E		
Minus 20%						*£ 147,000*		*£ -*	*£ -*	*£ -*	*£ -*	*£ 248,000*		*£ -*	*£ -*	*£ -*	*£ -*	*£ 170,000*	*£ 565,000*	
Central Estimate						**£ 184,000**		**£ -**	**£ -**	**£ -**	**£ -**	**£ 310,000**		**£ -**	**£ -**	**£ -**	**£ -**	**£ 212,000**	**£ 706,000**	
Plus 30%						*£ 239,000*		*£ -*	*£ -*	*£ -*	*£ -*	*£ 403,000*		*£ -*	*£ -*	*£ -*	*£ -*	*£ 276,000*	*£ 918,000*	

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