North Brook Weir Restoration Design

FINAL Report

Warwickshire Wildlife Trust

Quality information

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Contents

Glossary

Terminology	**Meaning**
2D modelling	Two-dimensional hydraulic modelling
Bed shear stress	Measure of the force exerted by moving water on the river bed
Bedload transport	Process of movement of sediment along the bed of a watercourse
Geomorphology	The study of the physical features of the surface of the earth and associated processes
Hydromorphology	The physical character and water content of water bodies
LIDAR	Light Detection and Ranging Data (provides a topographical surface)
Sediment transport	Process of movement of sediment along a watercourse

1 Introduction and Methodology

1.1 Background and Objectives

Warwickshire Wildlife Trust commissioned Dynamic Rivers to undertake survey, hydraulic modelling and detailed design for river and floodplain restoration, fish passage, habitat creation and NFM to bypass a weir on the North Brook, Coundon Wedge, Coventry. The study reach of the North Brook and weir location is shown below in Figure 1.1. Our approach fully considers the main aims of the project that include:

- Develop a preferred option for the mitigation measures on the weir working with WWT and partners;
- Complete flow and flood modelling for the preferred option;
- Complete detailed design specification for the preferred option;
- Complete a full cost break down for construction of the preferred option.

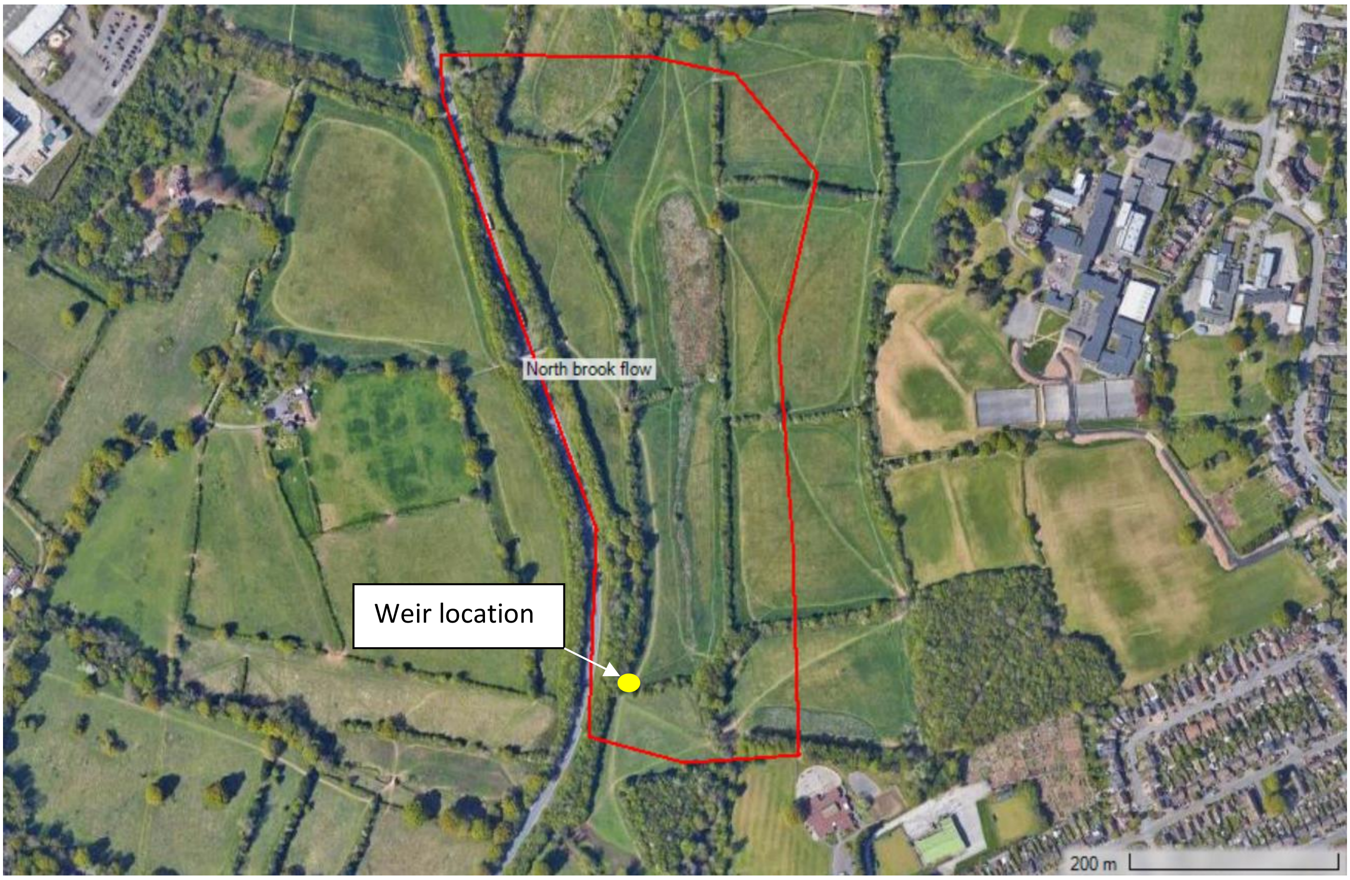

Figure 1.1 Study area of the North Brook and associated weir location.

1.2 Approach

We have gained a detailed understanding of the state, activity and sensitivity of the study watercourses through the study reach, through the review of archival maps and aerial photography illustrating system functioning over both historical and recent time. This was combined with a targeted walkover that helped confirm the previous optioneering work undertaken, landscape features identified during the desk study identifying sediment sources and sinks, geomorphological units and identifying geomorphological processes linked to the sediment transport and the likely channel change regime. All data were reviewed against the hydraulic modelling outputs.

We have also reviewed potential natural and artificial constraints to the proposed works and the walkover and desk study findings have been used to identify options from a fish passage, ecological habitat creation and geomorphological processes perspective. Options were shared with the client and steering group to allow selection of the preferred restoration measures to take forward to detailed hydraulic modelling and production of the detailed design.

We have quantified the geomorphological and flood risk impacts of the preferred restoration options for the North Brook reach, using a 2D hydraulic model (HEC-RAS, benchmarked by the Environment Agency) for the river, utilising information including Environment Agency LIDAR, new survey and existing EA hydraulic model information (flow information as no explicit coverage of the North Brook reach). The 2D modelling approach has been applied across both the river and valley bottom allowing inundation areas to be mapped. Data from the flow modelling across the flow regime in the form of shear stress was used to confirm impacts to the flow and sediment regime, to help size material for proposed restoration features, and to ensure they are appropriate for a naturally functioning watercourse of this type. The model was also used to determine impacts on the flood hydrograph downstream by monitoring the flow at the downstream end of the model and comparing it to the baseline outputs.

2 Data Review and Fluvial Audit

2.1 Desk Study

The North Brook has been subject to significant historic modification, through channel straightening and through the inclusion of infrastructure within the channel, including weirs and culverts. It appears that some weirs have been removed over time or failed, and this offers insight into how the watercourse may react to weir bypassing. North Brook has been completely realigned to one side of the valley bottom, leaving it perched in the floodplain compared to where it once naturally flowed, this palaeo channel (evident in the LIDAR – Figure 2.2) is to be targeted for a potential 'stage zero' approach to bypass this particular weir.

Given the degree of modification, it is difficult to determine from aerial imagery the current processes operating, however the optioneering report provided at the tender stage identifies that the channel is lined with silt in many places, indicating a generally depositional regime, but with evidence of gravel features further downstream, suggesting there may be a low-level supply locally or from upstream.

Straightening predates the earliest available OS Maps (1888 – See Figure 2.1) but aerial imagery (Figure 1.1) and the fluvial audit suggests there may have once been a pond in the northern section of the site that currently exists as a partly functional wetland.

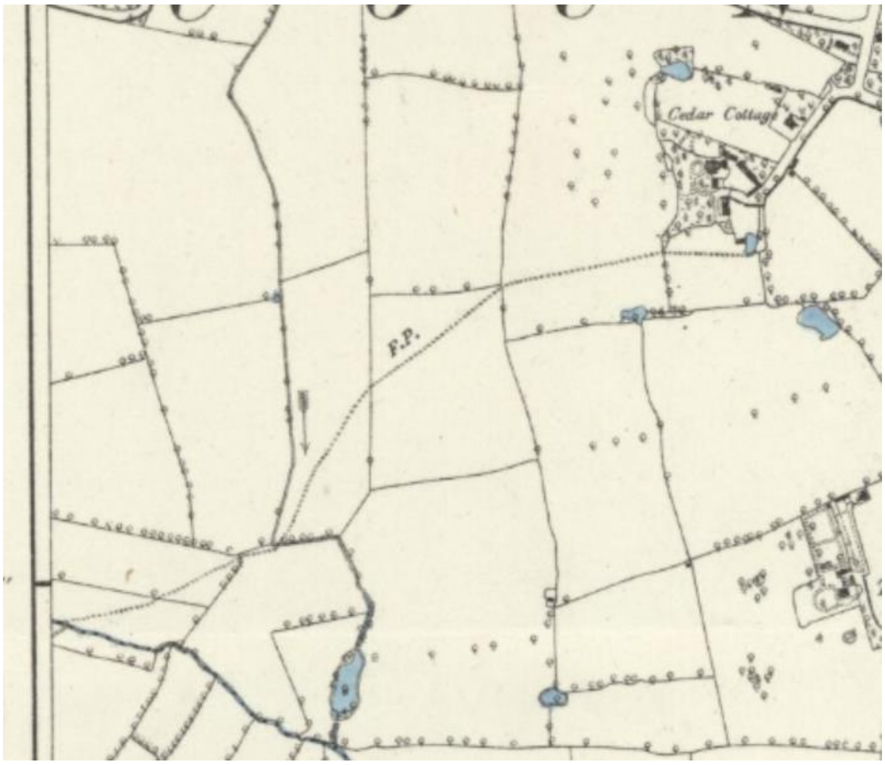

Figure 2.1 Historically more sinuous middle reach of the Erewash, 1888 Map.

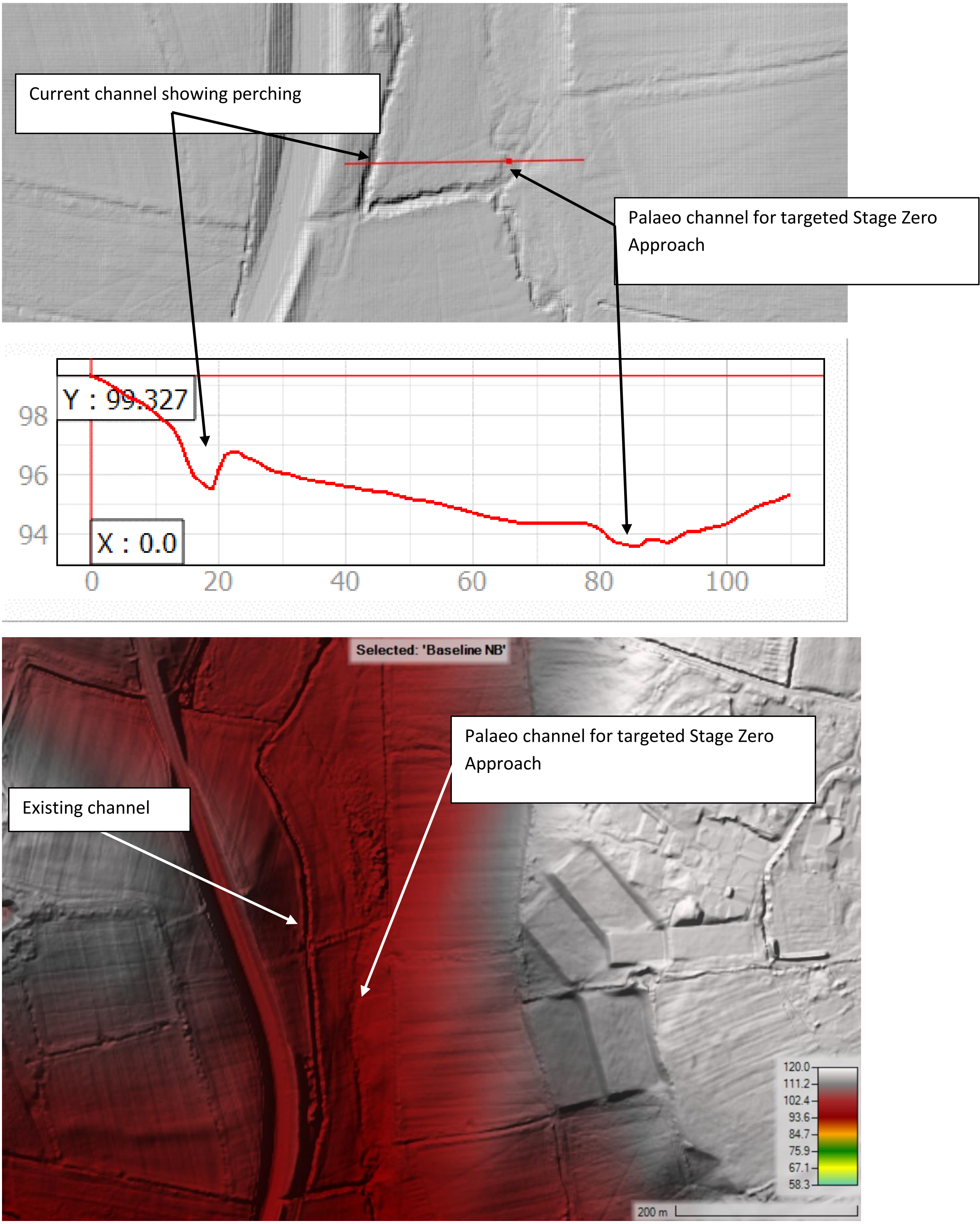

Figure 2.2 LIDAR and profile across study reach showing potential high-level opportunities and palaeo channel across the floodplain

The present watercourse flows mostly over river alluvium above the study reach but the historic straightening means this now flows against the valley edge, abandoning the alluvium along the palaeo channel route. These deposits overlay the Allesley Member sandstone and mudstone (Figure 2.3), with this bedrock layer visible in places along the realigned channel route, and it is believed the weir structure could be founded on bedrock. The dominant control on current river processes is the drift geology and alluvium along the upper study reach area, where present along the current main channel (Figure 2.4) although any reworking is presently impacted by the historic dredging, straightening and over-deepening and resultant floodplain disconnection.

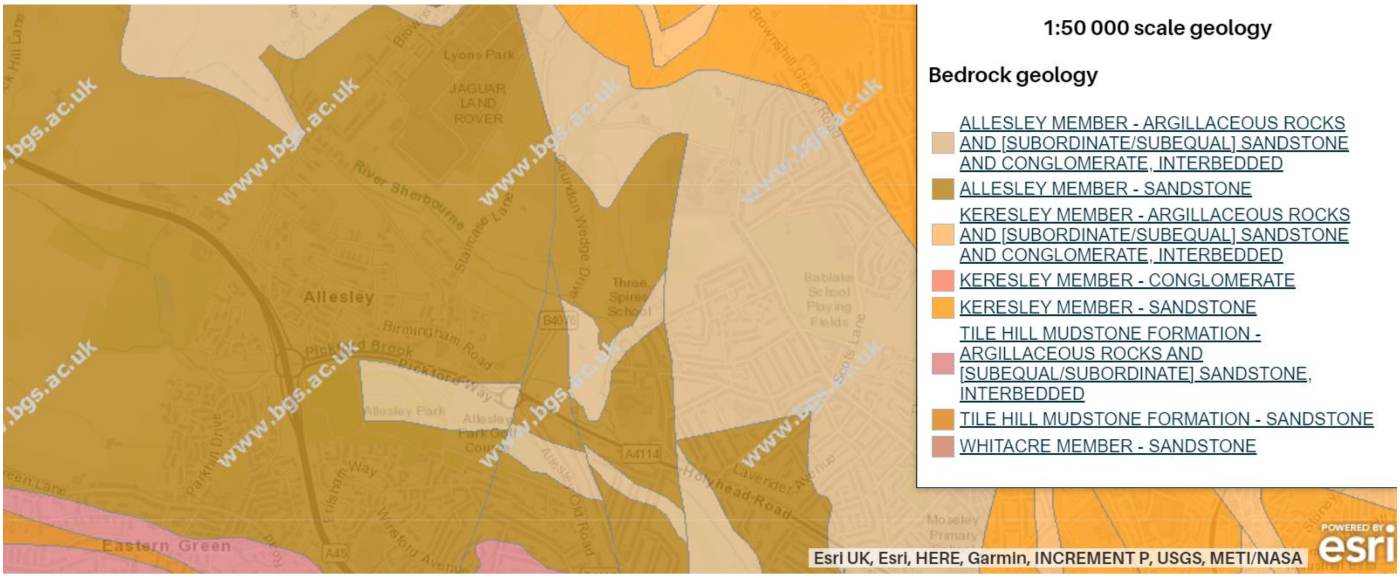

Figure 2.3 Bedrock geology of the North Brook study reach at Coundon Wedge

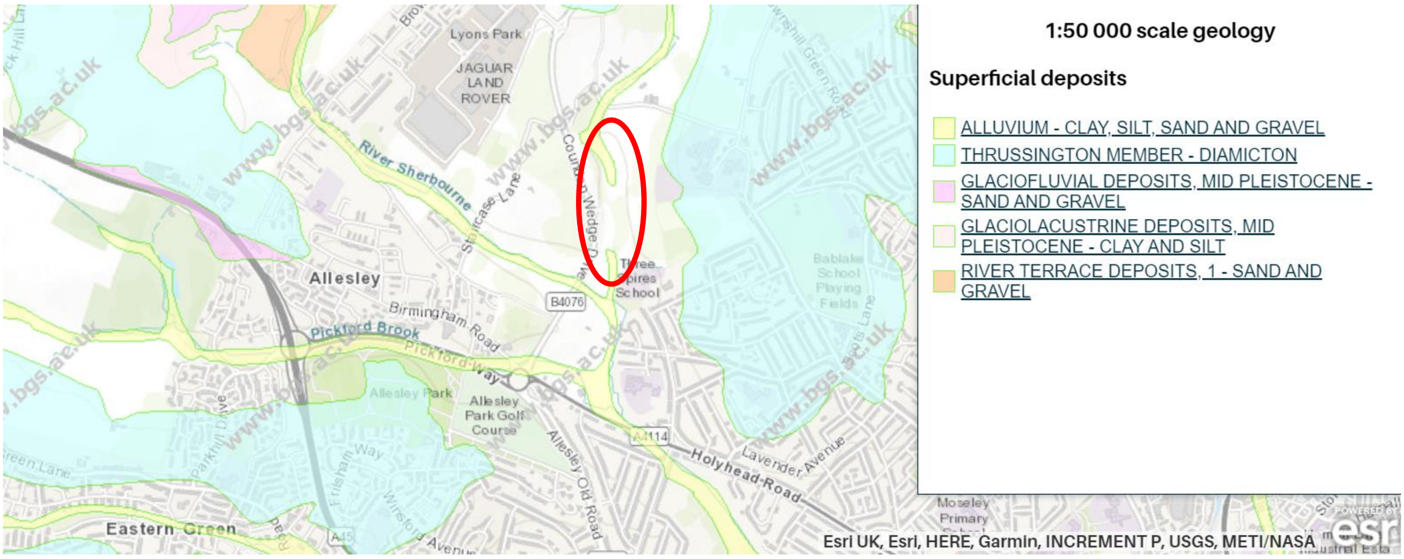

Figure 2.4 Drift geology of the North Brook study reach at Coundon Wedge

Overall, the desk study suggests a low to moderate energy, heavily modified river channel flowing over Holocene alluvium in places but with clear evidence of historic straightening and over-deepening. The weir itself may be founded on the bedrock layer. Detail on sediment character, sediment transport and channel and floodplain dynamics are discussed further in the field audit.

2.2 Field Study

The fluvial audit undertaken for the purposes of this project found that the watercourse has been subject to significant historic modification as identified in the desk study, through channel realignment/straightening to the valley edge, with presence of structures in places within the study reach including the weir and immediately downstream of the study reach where another obstacle to fish passage exists.

The palaeo channel is still well defined in the left bank floodplain, with the southern area of the channel being fed by a ditch originating from the left-hand valley edge, see Figure 2.5 (facing downstream). This section of the channel is fairly confined within the valley bottom, offering limited opportunity for wider floodplain works alongside reconnection. The wetland area within the northern section of the study area is possibly a former pond with presence of several wetland species including soft rush, common sedge, common reed yellow flag, creeping buttercup and young willow (Figure 2.6). Several flow routes are evident north of this wetland area (Figure 2.7) that could be targeted as part of this stage zero approach for reconnecting this floodplain area and bypassing the weir. Flows are likely to spread across this wetland area to the north of the site once reconnection takes place. Flows along the southern section of palaeo channel currently flow back into the main channel close to the footpath, a section of ground could be lowered to spread flow across a wider area when it reconnects to the existing channel to reduce the risk of frequent flooding across the footpath (Figure 2.9). The watercourse splits locally and displays active medium gravel bed and bar features (Figure 2.9) immediately downstream before it reaches the next weir and pond structure.

The current watercourse is reasonably well connected to the floodplain along the reach where the upstream reconnection to the palaeo channel is being considered (Figure 2.8), with channel depths generally not exceeding 0.5m. It becomes deeper in places where it flow north to south along the valley edge, with several crossing points and pipes impacting the flow and sediment regime. The weir itself being bypassed as part of this scheme is formed of a culvert underneath a footbridge (Figure 2.10) which presents a complete obstacle to fish passage. The head difference across it is approximately 0.75-1.0m and is in a poor overall state with some flow bypassing the culvert and around the structure, and some scour where flow now exits the culvert.

There is a ditch running north to south along the eastern boundary of the existing wetland in the northern study area, this takes a 90deg turn before discharging into the palaeo channel downstream of the wetland. This offers opportunity for connection into the wetland area and has been explored as part of this project.

Figure 2.5 Palaeo channel along valley bottom of southern field looking upstream

Figure 2.6 Existing wetland area diversity

Figure 2.7 View of palaeo channel to be reconnected at upstream end of reach towards existing wetland

Figure 2.8 View of upstream left bank reconnection area where scrub and trees will need to be removed

Figure 2.9 View of downstream reconnection area showing gravel bed and bar features

Figure 2.10 View of existing culvert and weir

In general, the field audit supports the desk-based findings of a formerly lowland active meandering main channel, but which has suffered as a result of historic realignment, over-deepening, in-channel structures and straightening. Gravel features and habitat downstream of the study reach suggest a low level of supply from upstream. The palaeo channel offers a strong opportunity for reconnection to provide a ‘stage zero’ type approach and to provide fish passage around the structure. These options are summarised and discussed further in Section 3.1.

3 Optioneering, Modelling and Design

3.1 Optioneering

Initial review and identification of options following the field audit and initial hydraulic modelling (see section 3.2), has been undertaken, with options proposed that work with the principles of a ‘stage zero’ type approach to reconnecting the palaeo channel and providing fish passage around the weir structure. These options are shown below, including how these relate to the topography, in Figures 3.1 and 3.2 alongside the benefits linked to these options, and example features provided in Figures 3.3 to 3.7.

Figure 3.1 Identified options at upstream end of study area along the North Brook

Figure 3.2 Identified options at downstream end of study area along the North Brook

Once implemented the floodplain zone will become an active anastomosed area with multiple flowing channels interacting with online pools and live and dead wood. Examples of likely functional form are given below but it must be remembered that projects scales and volumes of water and sediment will differ between sites so these should only be viewed as indicative.

3.1.1 Channel and ditch blocking

To achieve reconnection of the palaeo channel through the 'stage zero' type approach to providing fish passage at the site, channel blocking of the existing watercourse is proposed to divert flow into the palaeo channel network (alongside some local ground lowering). This will encourage the development and improvement of wetland through the rewetting of valley bottom and marginal areas through channel and ditch blocking. Example areas where this principle has been applied are shown in Figures 3.3 and 3.4.

Figure 3.3 Example large wetland area created by through tributary blocking of Milkeld Sike on the Lowther Estate. Indicative of possible winter / rainstorm wetting of the North Brook site.

Figure 3.4 Diffuse valley side flow network created by drain blocking in the Swindale Valley. Indicative of possible high summer wetting of the North Brook site.

3.1.2 Palaeo channel reconnection through ground lowering

Figure 3.5 is an image on the River Lowther where a palaeo channel was reconnected to encourage wetting, similar to the principles of the palaeo channel reconnection proposed here. This was achieved through creating a breach within the embankment into the palaeo channel at the up and downstream ends to allow flow into it under elevated discharges and through introduction of gravel riffle features to raise normal water levels locally. Figure 3.6 shows the improved ecological diversity created following work undertaken to fully reconnect another palaeo-feature on the same river.

Palaeo channels can be either partly or fully reconnected and involve either retention of the current main channel or abandoning it. Alongside this, wetland creation can be achieved by ensuring the reinstated channel is well connected to the floodplain. If the current main channel is maintained as part of reconnecting the palaeo channel, then flood capacity could be increased with careful design providing important NFM benefit.

Figure 3.5 Palaeo-channel backwater reconnection on the River Lowther. Indicative of possible winter wetting of the North Brook site.

Figure 3.6 Example reconnected palaeo channel on the River Lowther. Indicative of possible winter wetting of the North Brook site.

3.1.3 Wood features

Live and dead wood can enhance in-channel diversity and increase overbank flooding or can be used as dead wood features in the floodplain. Impact is greatest where wood is also coming down the system to help enhance accumulations. The roll of live wood and other marginal and aquatic vegetation in influencing channel and floodplain development in low to moderate energy rivers is little researched but vitally important and restoring wood reintroduces a missing natural influence on these systems (Figure 3.7).

Figure 3.7 Alder pushed over in Swindale Beck to encourage channel avulsion processes.

3.2 2D Flow Model Construction

To help identify and assess the options for the study reach of the North Brook at Coundon Wedge described in section 3.1 above, a 2D HEC-RAS model of the study reach has been developed, using available Environment Agency 1 m cell size LIDAR, existing Environment Agency hydraulic model information (flow information in this case as no explicit representation of this Brook) and new survey data of the channel where reconnection to the floodplain is being proposed. The model was developed at a 1 m cell size to enable accurate representation of the channel, and floodplain, that were of significant importance for the opportunity assessment and design elements for this project. The hydrology supplied within the Environment Agency hydraulic model was utilised for the purposes of this modelling assessment.

The purpose of the modelling was to appraise the feasible options identified in Section 3.1 above. This enabled assessment of the impacts to in-channel processes and the hydrological regime and iteration of these features to provide the optimal benefits. The model has also assessed the impact on flood risk both locally and downstream through use of a flow monitoring line at the downstream extent of the model.

The model has been built using a Digital Elevation Model (DEM) across the model domain that provides a ground elevation value for each 1 m grid cell. The model extent is shown in Figure 3.24 below.

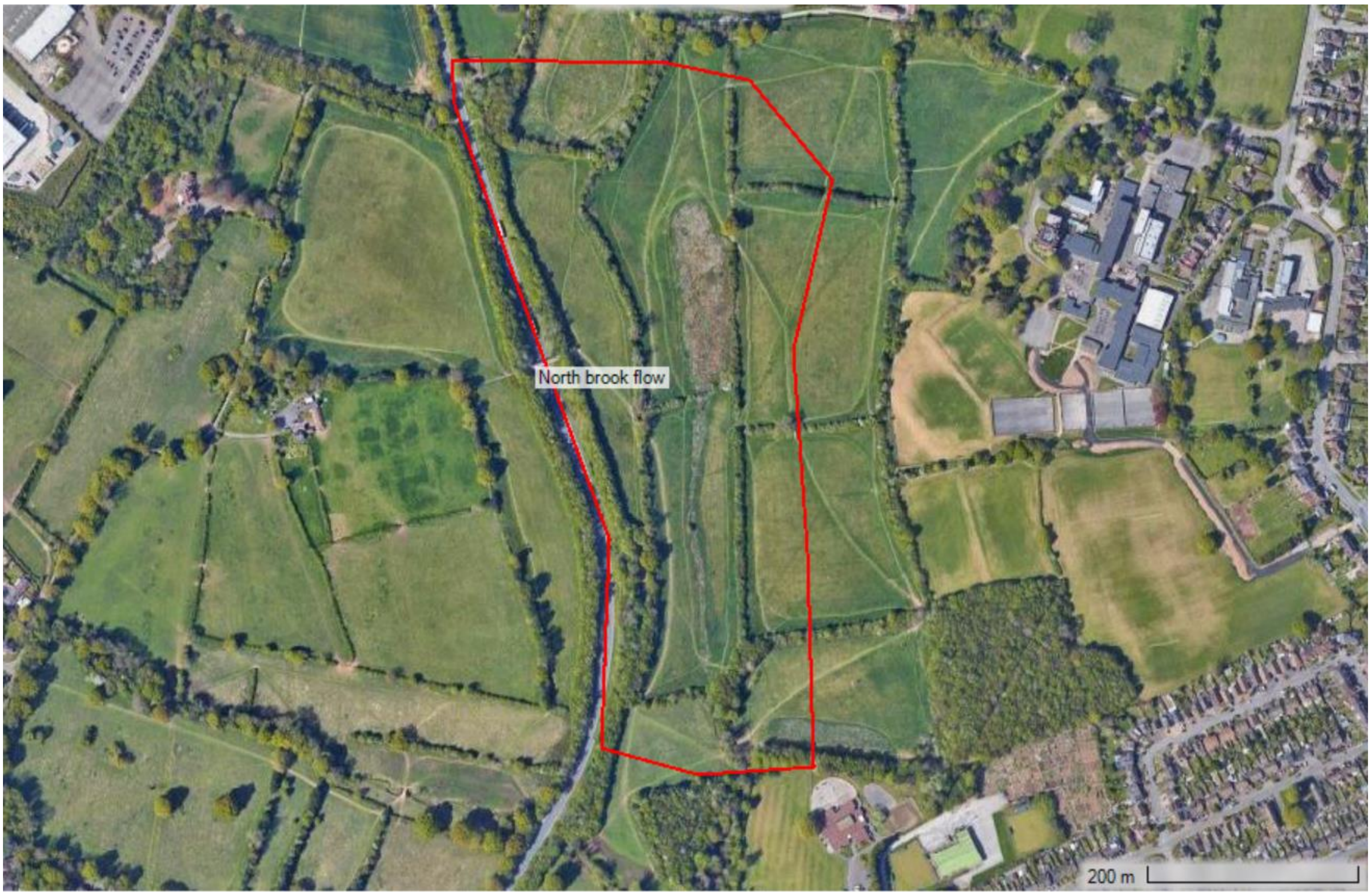

Figure 3.8 Model extent for North Brook study reach

3.3 Model Run Parameters

Simulated depths, velocities, water level, bed shear stress, flow and mass balance were output to assess flood extents across the model domain. Monitoring lines were used at the downstream end of the model to determine likely downstream flood risk impacts. Model outputs were sensibility checked to ensure these reflected information gathered during the Fluvial Audit undertaken prior to the modelling and model results were deemed to be appropriate and sensible.

3.4 Hydrology

Flow inputs to the upstream end of the 2D model domain for the North Brook were derived from the hydrological information provided by the Environment Agency for this project. For the purposes of this design assessment, a 100yrCC, 20yr and 2yr return period flood event have been run through the model as well as representative low flows Q95 (typical summer) and Q10 (typical winter), estimated using Low Flows 2 software to determine hydraulic habitat change. The corresponding flows were:

- 100yrCC – 2.23m^3/s
- 20yr – 1.29m^3/s
- 2yr – 0.68m^3/s
- Q95 – 0.05m^3/s
- Q10 – 0.2m^3/s

A small flow was also applied to the ditch targeted for infilling works.

3.5 Utility information

A services search has been conducted for the site (Figure 3.9). This revealed that no services are likely to be impacted by the proposed works, however the sewer line running north to south within the study area should be considered carefully by the contractor undertaking the works in terms of access and crossing this utility. It should be noted that standard services searches do not identify all local land drains. If encountered, these should be managed on site by the contractor and client. The contractor should review the services search drawing prior to construction and for potential access routes as some may be crossed to deliver the works.

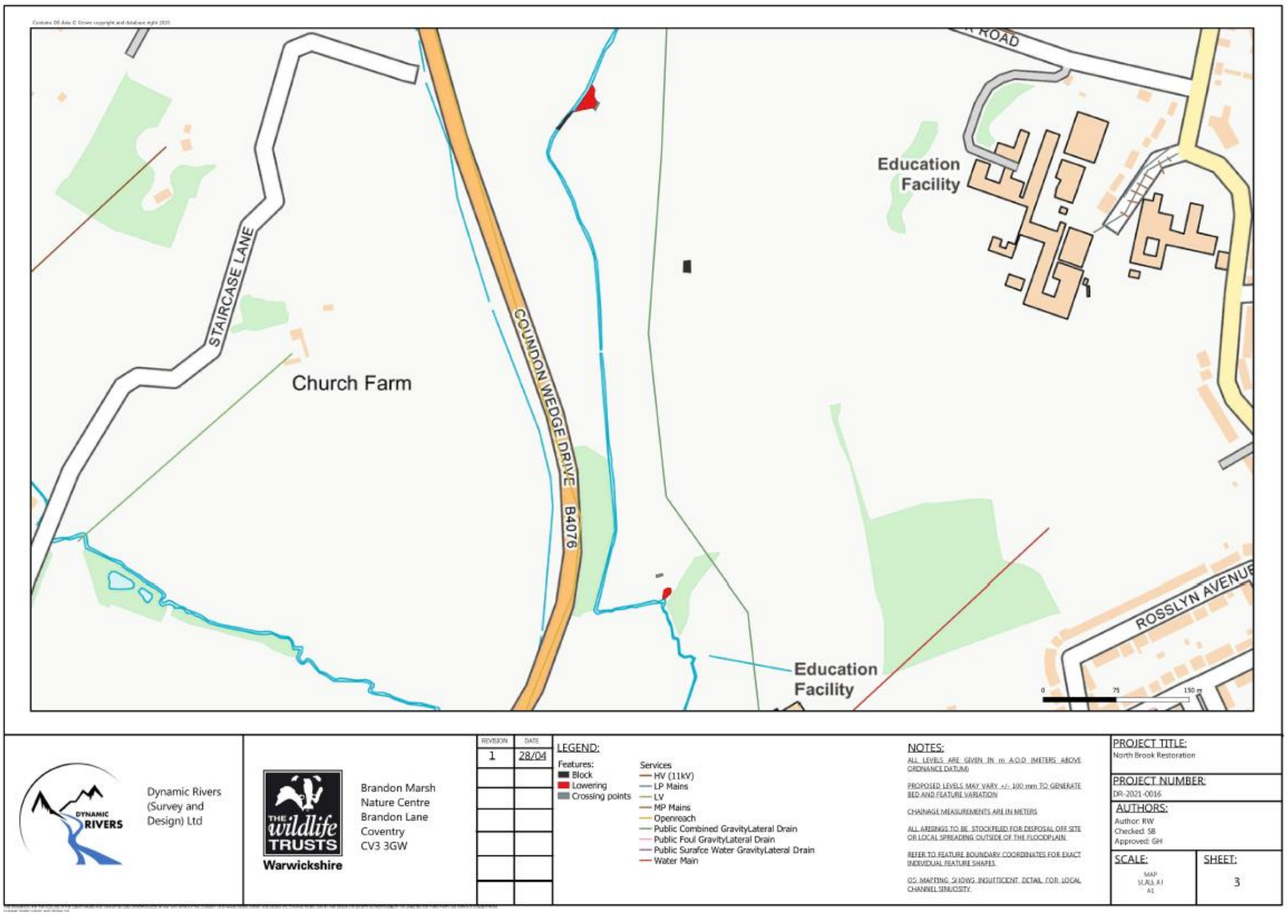

Figure 3.9 Proposed restoration design and utilities service search information

3.6 Final Design

The preferred restoration design option is shown in Figure 3.9 above following liaison with the client and stakeholder group. Detailed design drawings have been produced alongside a Method Statement that outlines how a contractor might safely deliver the works, a Designers Risk Register that highlights all risks related to the project and a Bill of Quantities with associated estimated costs. The below sections outline the bed shear stress review that has undertaken to understand the influence of proposed floodplain connectivity improvements compared to baseline, hydraulic habitat gains linked to the preferred restoration scheme and the flood risk impacts as a result of the preferred scheme design.

3.7 Bed Shear Stress

Baseline bed shear stress model outputs show that generally under extreme flows values range between 5-60N/m^2 (Figure 3.10) with the majority of these falling within the lower estimate of this range. This range does not change significantly for the restored model scenario as there is already good connectivity to the floodplain under baseline conditions due to the depth and perched nature of the channel meaning flows spill out into the floodplain under low order floods. The restored model scenario mainly creates a larger wetted area with low bed shears showing a generally depositional environment, particularly across the existing wetland area. This is expected given the topography and desired wetland creation in this area. Shears are higher through the more defined channel in the southern field, but still do not generally exceed $60N/m^2$ under extreme flood conditions. Therefore, extreme erosion is unlikely to occur along this reach.

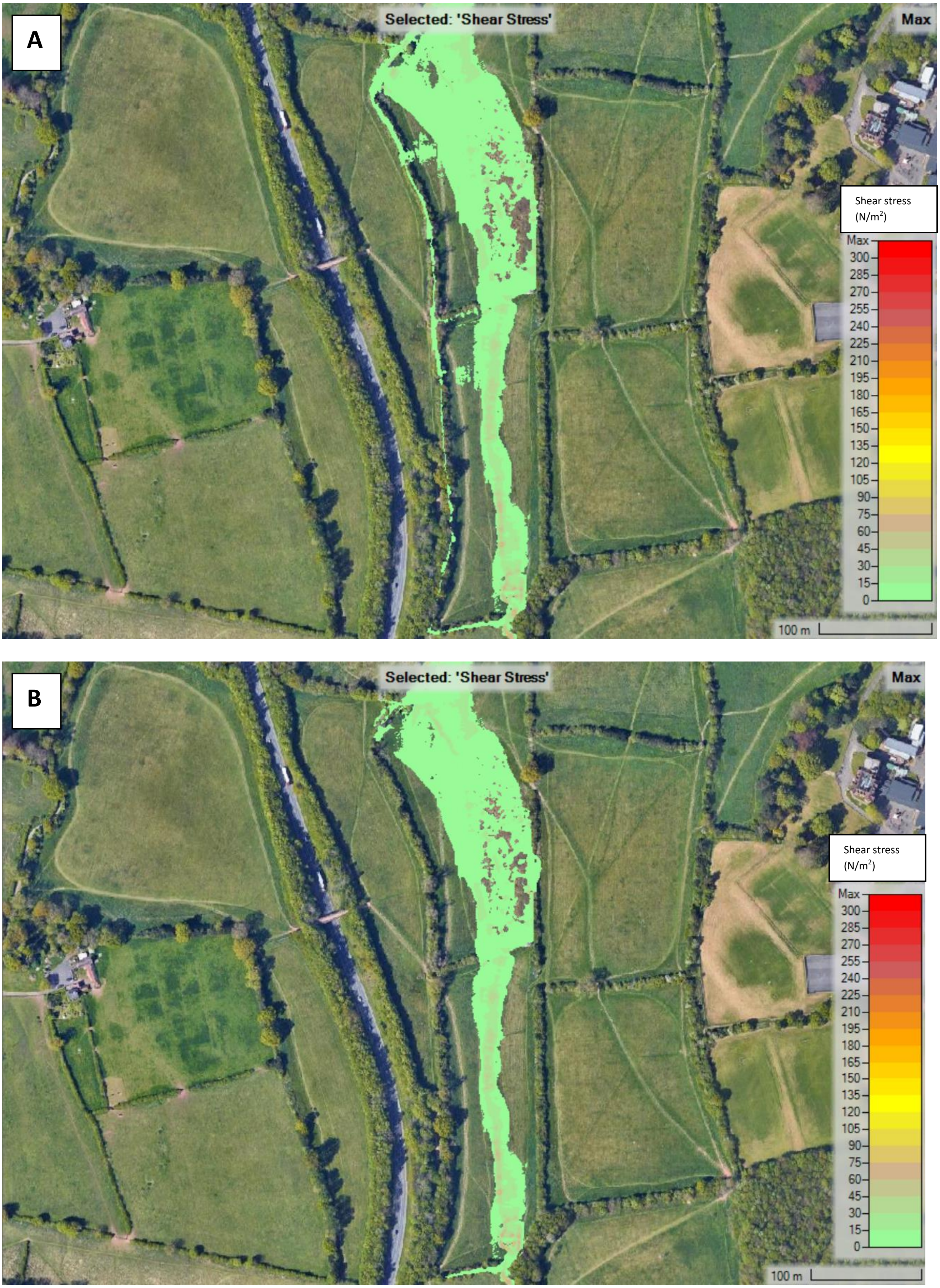

Figure 3.10 Predicted extreme shear stress levels across the baseline (A) and restored (B) along the North Brook Study Reach.

3.8 Hydraulic Habitat

Figure 3.11 shows the hydraulic habitat change, compared to baseline, under strong summer flow conditions as a result of the preferred scheme design.

There is a change in both hydraulic habitat diversity and, significantly, in overall hydraulic habitat area as a result of the preferred scheme for a strong summer flow. There is increase in higher energy biotopes overall as a result of the impact of the weir on current flows in the main channel. Otherwise, there is a strong diversity in overall hydraulic habitat suggesting a complex of wetland habitat will be created as a result of the scheme. There is also a very significant increase in overall hydraulic habitat area when compared to baseline under the same flow conditions, increasing from ~3850m^2 to 5660m^2. This is a result of the overall improved connectivity to the floodplain and associated wider wetted area and is a very significant gain as a result of the proposed scheme.

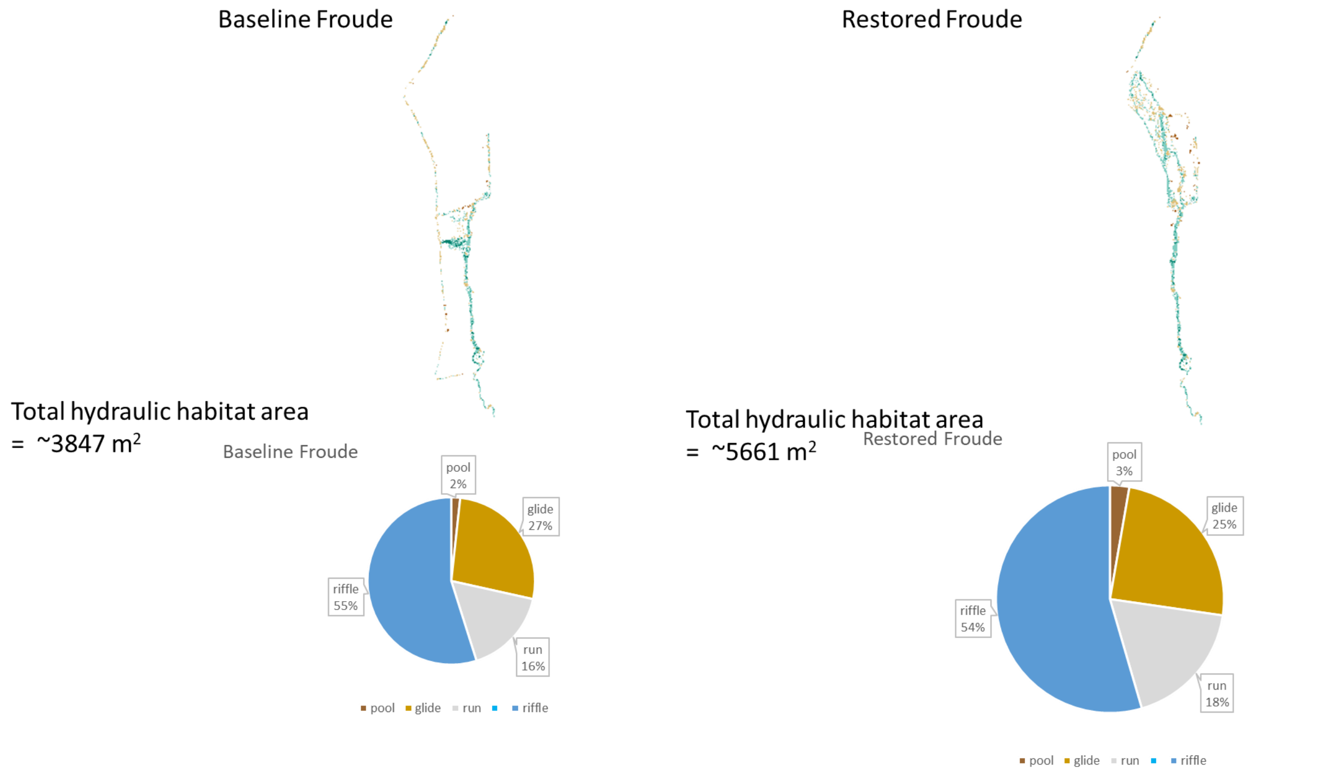

Figure 3.11 Strong summer flow hydraulic habitat / biotope change compared to baseline for entire study reach and associated overall habitat area and diversity change (pie charts scaled to area).

3.9 Flood Risk

Flood modelling for the current and restored site scenario has been undertaken to determine the fluvial flood risk impacts as a result of the proposed scheme. This has been undertaken for the 100yr plus allowances for climate change, 20yr and 2yr event. Low flows and associated restoration impacts are discussed in the section above with regards to habitat changes.

Figures 3.12 to 3.14 demonstrate the flood extent changes for each of the flood return periods listed above, with baseline shown in blue and the restored scenario shown in red (no change areas are shown in purple). The figures show some increases in flood extents within the site boundary where the design is encouraging improved floodplain connectivity for all flows as part of the 'stage zero' design, this is expected and an objective for the scheme. This results in flood extent reduction along the current main channel and where flows are shown to spill out on the left bank further downstream.

Figure 3.12 1 in 100yrCC flood extent change, blue = baseline, red = restored (where red is visible indicates flood extent increase, purple indicates no change and blue indicates reduction in flood extent).

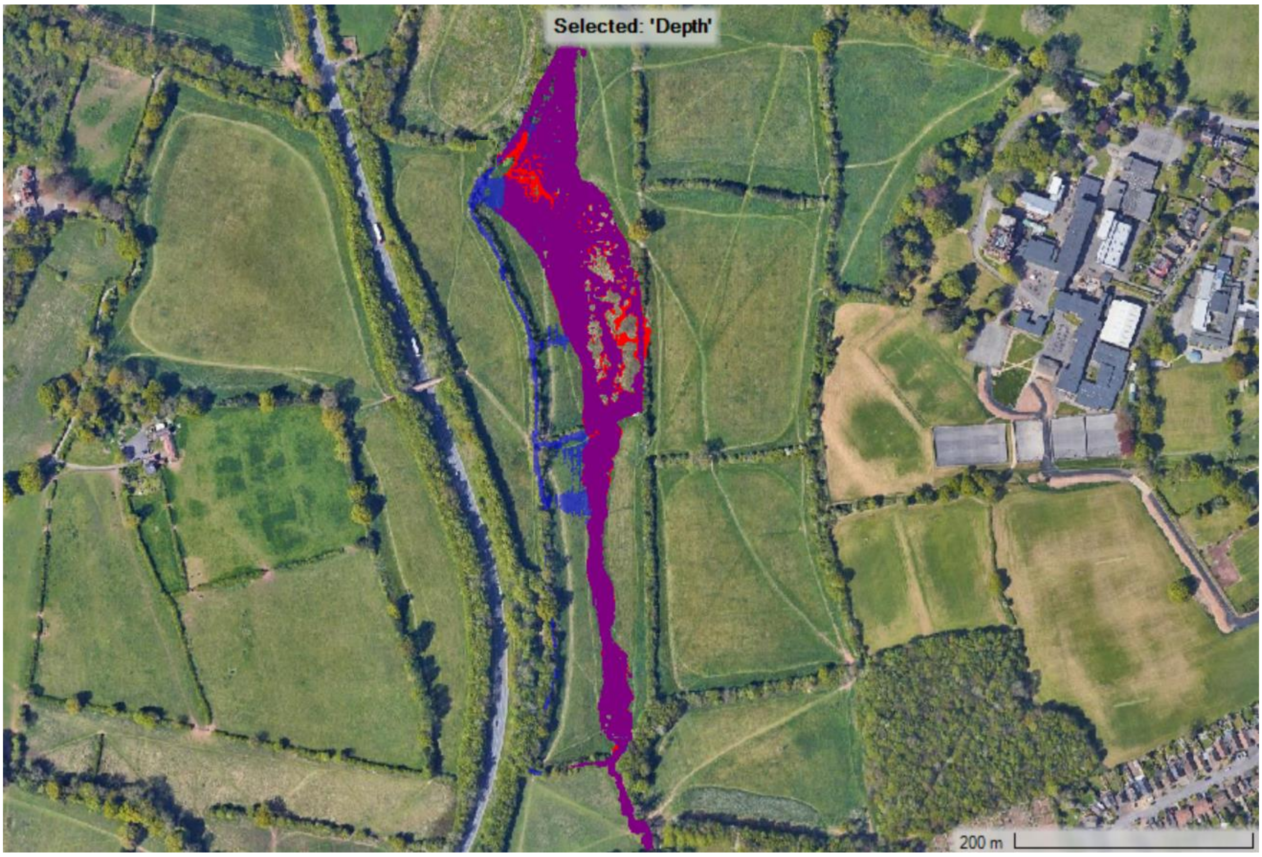

Figure 3.13 1 in 20yr flood extent change, blue = baseline, red = restored (where red is visible indicates flood extent increase, purple indicates no change and blue indicates reduction in flood extent).

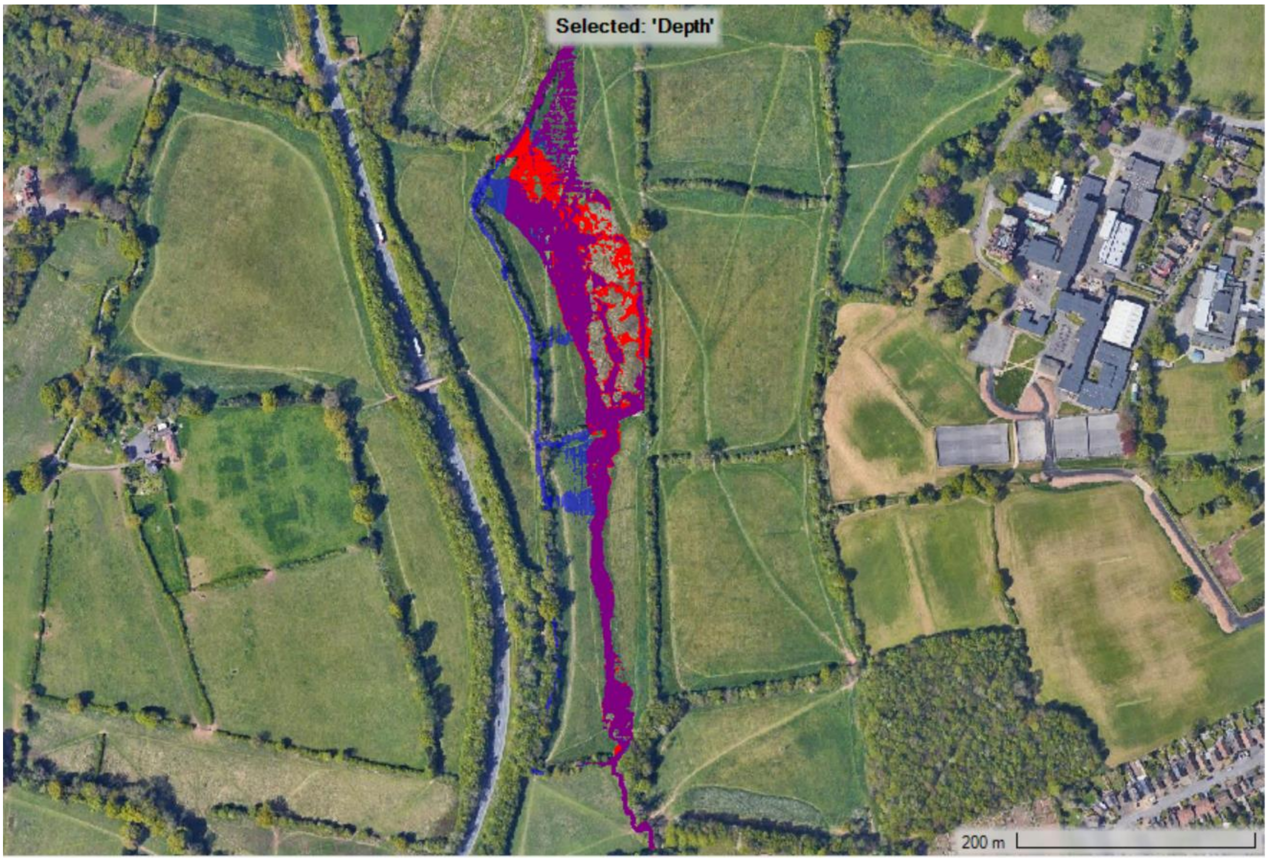

Figure 3.14 1 in 2yr flood extent change, blue = baseline, red = restored (where red is visible indicates flood extent increase, purple indicates no change and blue indicates reduction in flood extent).

Downstream, the impact of the proposed works across all the modelled extreme return period flows is negligible with no significant changes in the flows monitored at the downstream extent of the model when compared to baseline. This is unsurprising given that flood flows do spill out into this area under modelled baseline conditions anyway. This is demonstrated in Figure 3.15 below. This concludes that there is no increase in downstream flood risk as a result of the proposed works.

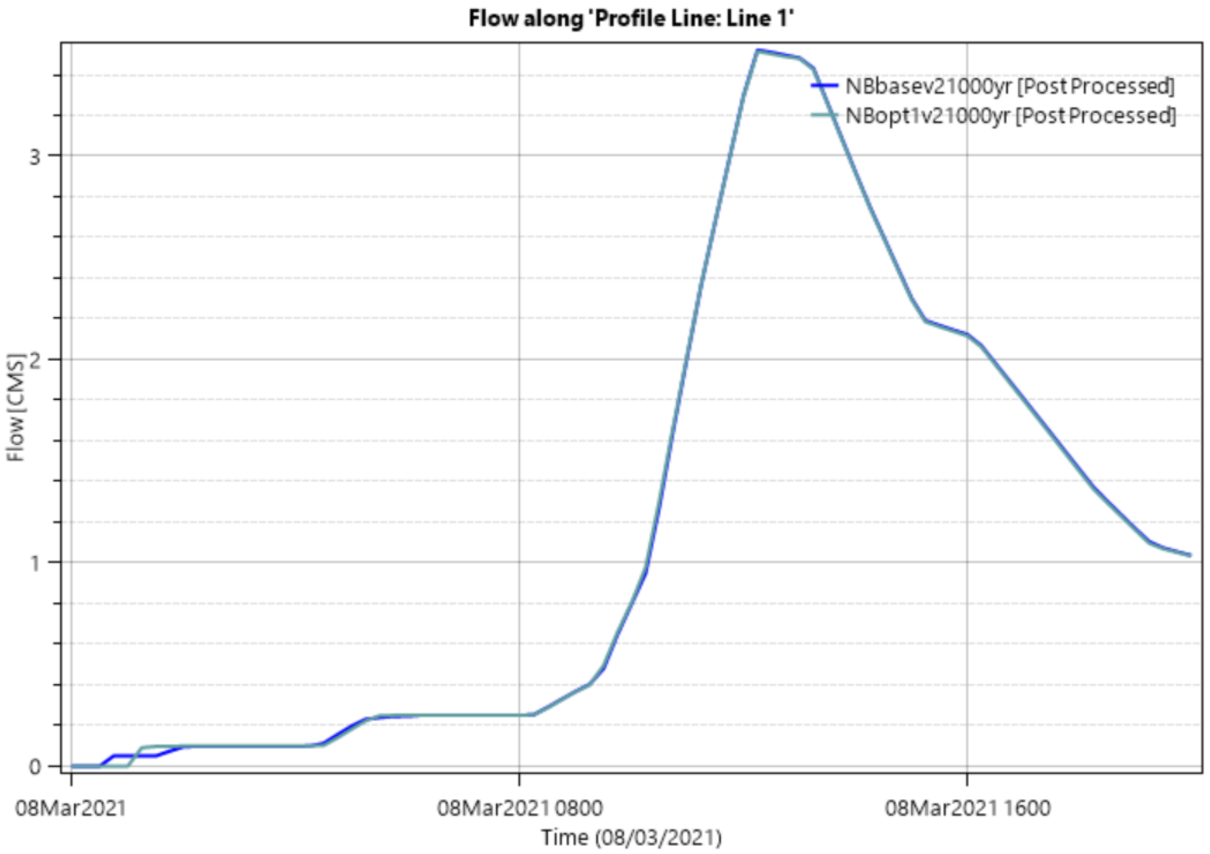

Figure 3.15 Downstream flood hydrograph change across all modelled flows.

4 Conclusions and Recommendations

4.1 Conclusions

- The North Brook study reach at Coundon Wedge, Coventry has been historically modified as a result of channel realignment, straightening and the introduction of in-channel structures. The weir along the study reach forms a complete barrier to fish passage and an option has been identified to bypass the weir structure using a palaeo channel evident in the natural valley bottom. The option developed has retained as many principles of the 'stage zero' restoration approach as possible;

- The field audit supports the desk-based findings of a formerly lowland active meandering main channel. However, the gravel morphology downstream of study reach suggests some supply of smaller gravels from upstream and locally that would support a more diverse in-channel feature mosaic and this could develop over time as the system naturalises following restoration. Only minor works are required to reconnect the identified palaeo channel through blocking of the current main channel, and some local ground level lowering to divert all flow into the new channel network and wetland area. This will move the channel into its natural valley bottom, reconnect the floodplain, improve wetland habitat and provide some NFM benefit;

- Hydraulic modelling has demonstrated the ability of this restored reach to create a functional restoration scheme with improved floodplain connectivity to encourage the wider development of wetland habitat across the reconnected areas. This provides a naturalised approach to fish passage around the weir structure;

- Modelling has also shown that there are no negative flood risk impacts associated to the scheme;

- Hydraulic habitat mapping also shows a significant area increase in available hydraulic habitat as a result of the scheme. This is a result of the increased wetted area created through the improved floodplain connectivity created as part of the scheme design.

4.2 Recommendations

- It is critical that the hydraulic regime across the site is in line with the newly created features to ensure the site will function, it is recommended that a geomorphologist supervises the site works during construction, as detailed in the accompanying Method Statement.