LIFEDeeRiver

Restoration of Freshwater Features

LIFE18 NAT/UK/000743

Natural Resources Wales

Erbistock Weir

Final Report

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Quality information

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01	17/03/21	Addressing NRW comments	GW	Gill Wright	Principal Aquatic Ecologist

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1. Introduction

1.1 LIFEDeeRiver Project Overview

The River Dee is the largest river in North Wales and together with Bala Lake (Afon Dyfrdwy a Llyn Tegid) is designated as a Special Area of Conservation (SAC). Atlantic salmon (*Salmo salar*), listed under Annex II of the EC Habitats Directive (92/43/EEC), are a primary reason for selection of the site. Annex II species present as a qualifying feature include sea lamprey (*Petromyzon marinus*), river lamprey (*Lampetra fluviatilis*), brook lamprey (*Lampetra planeri*) and bullhead (*Cottus gobio*). Other species of conservational interest include sea/brown trout (*Salmo trutta*) and European eel (*Anguilla anguilla*). However, the Dee is significantly regulated, with three upstream reservoirs supplying potable water, historically modified banks and floodplains and fourteen weirs considered to impact fish passage. Consequently, some protected species and habitats have been categorised as unfavourable-bad or unfavourable-inadequate.

The LIFEDeeRiver project (LIFE18 NAT/UK/000743) aims to take a catchment-based approach to restore natural processes, features and habitats over a 55 km or more stretch of the SAC, contributing towards implementation of the Habitats Directive, Water Framework Directive (WFD) and other national and EU policies.

1.2 Study Overview

This project contributes to a number of the LIFE project's key aims, including improving longitudinal connectivity for fish and restoring or improving natural physical processes, features and habitats. Specifically, investigation into fish passage solutions at six obstructions (weirs) were required as part of the Restoration of Freshwater Features project: Horseshoe Falls, Llangollen Upstream and Downstream, Morlas Ford, Erbistock and Chester. At the start of the project, Natural Resources Wales (NRW) identified a number of preferred solutions for fish passage:

- Horseshoe Falls weir: Nature-like by-pass channel on right hand bank (RHB);
- Llangollen Upstream weir: Creation of at least three notches at bed level within the weir crest (~8-10 m wide);
- Llangollen Downstream weir: Remove remains to bed level and create a natural river channel;
- Morlas Ford weir: Ford removal and river channel restoration, access to the opposite bank via a clear span bridge;
- Erbistock weir: Partial removal to bed level of ≥ 50% of the weir's width;
- Chester weir: Either: 1) Improvements to the existing fish pass wall and notch in crest for smolt passage downstream; 2) Notch the weir crest for downstream smolt passage, or; 3) Bypass channel on the left hand bank (LHB).

1.3 Study Aims

The objectives of the study were to collate pre-construction information from a variety of environmental disciplines for each of the six weirs, including ecology, geomorphology, hydrology, heritage, topographic survey, utilities and contaminated land to assess the preferred options at each site, determine a recommended option and produce conceptual designs.

1.4 Report Structure

A review of the study area and catchment, including geomorphology and hydrology was conducted (Section 2). A standard methodological approach was subsequently applied to each weir, covering hydromorphology, water and sediment quality, contaminated land, ecology, heritage, topography, utilities and a low flow hydraulic study (where appropriate and dependent on site) and is reported in Section 3. Section 4 details the findings for Erbistock weir, utilising these in the context of hydraulic design and fish passage review to assess and identify the recommended solutions for fish passage. Concept design schematics are provided for final recommended options. Findings for the other weirs are detailed in separate reports.

2. The Study Area

2.1 Catchment Overview

The River Dee (Afon Dyfrdwy) rises in the mountains of Snowdonia National Park. The river then flows generally in an easterly direction through the Vale of Llangollen to Worthenbury. From Worthenbury it flows north through open lowland to the estuary at Chester. The length of the River Dee from Bala Lake to Chester weir is approximately 130km[1] (Figure 2-1). The catchment area of the River Dee (Afon Dyffrdwy) at Chester weir (the tidal limit) is reported to be 1,817km^2.

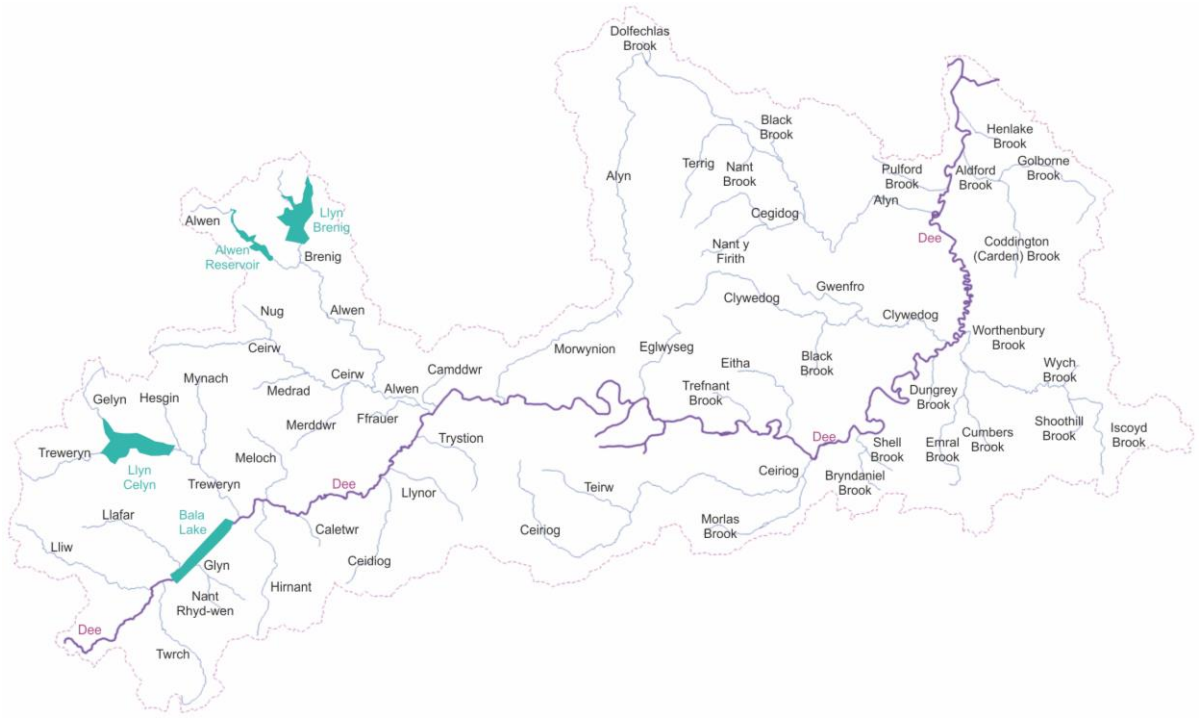


Figure 2-1. Catchment map for the River Dee

Land use in the river catchment is predominantly grassland, reported to be the 63% and extended all over the catchment. Woodland and mountain heaths and bogs represent the 13% and 9%, respectively, of the catchment and are mainly located in the upper catchment area. A further 9% of the catchment is arable and 6% is urbanised and located in the lower catchment area[2].

The River Dee has been characterised as a dynamic gravel-bed river with evidence of active channel migration in specific locations[3]. The river has been designated as a SAC and parts of the system are also notified as Sites of Special Scientific Interest (SSSI) for geomorphological and physiographical features.

Six weirs located in the Dee catchment have been selected for fish passage improvements as part of the present study (Figure 2-2):

- Horseshoe Falls weir;
- Llangollen Upstream weir;
- Llangollen Downstream weir;
- Morlas Ford weir;
- Erbistock weir (Section 4); and
- Chester weir.

[1] JACOBS (2013). B1867400 River Dee SSSI Restoration - Technical Report_Final.doc
[2] National Flow Archive – Dee at Chester Suspension Bridge. https://nrfa.ceh.ac.uk/data/station/info/67033
[3] Hill, C. and Emery, J. (2004), *'Fluvial Audit of the River Dee'*

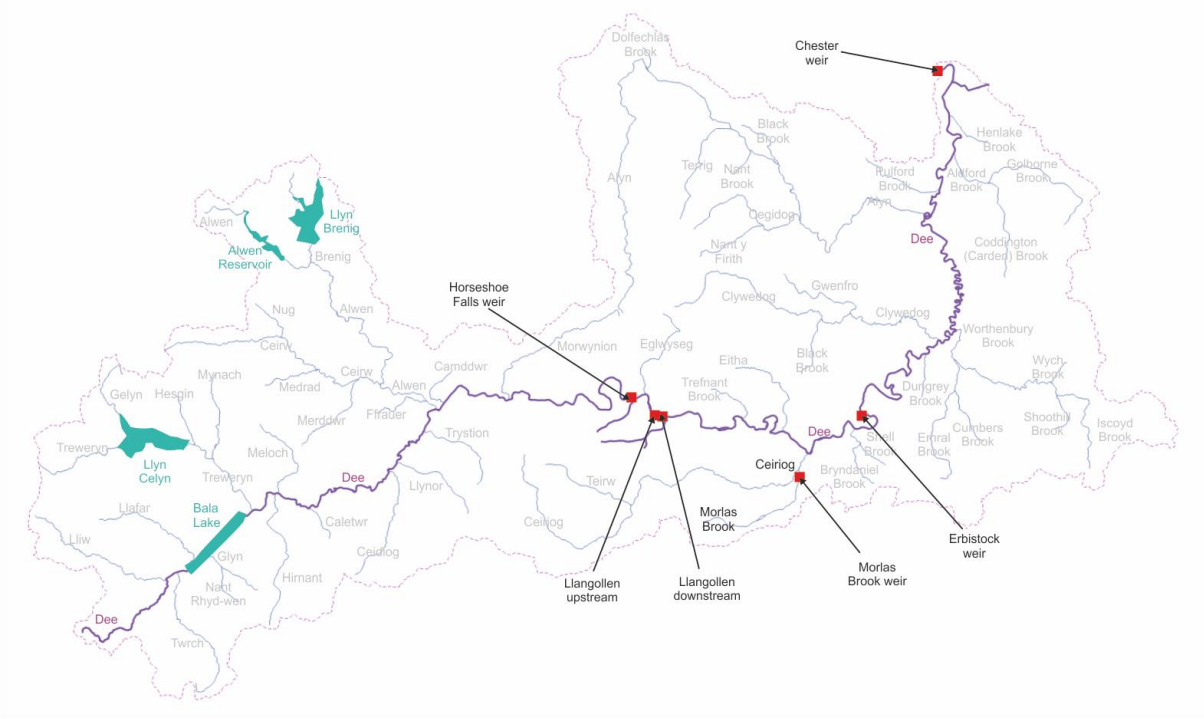


Figure 2-2. Six weirs located in the Dee catchment selected for fish passage improvements

More detailed baselines in the vicinity of Erbistock weir are discussed further in Section 4.

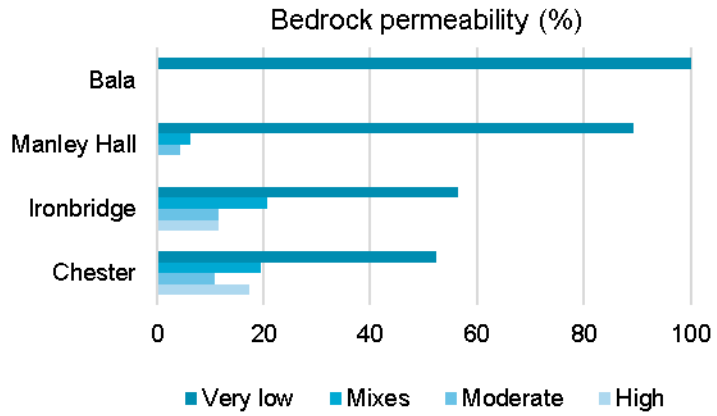
2.2 Catchment Geology/ Hydrogeology

The course and topography of the River Dee have been largely influenced by glaciers. At the upper catchment, a thin soil covers over mostly impermeable Paleozolic and volcanic rocks. Between Bala Lake and Chester the River Dee flows over predominantly sedimentary bedrock consisting of mudstones, sandstones and siltstones. Much of the bedrock is overlain with unconsolidated drift deposits with intermittent unconsolidated drift deposits[4].

The geology of the catchment is reflected in the bedrock permeability and in turn dictates base flow contributions to the river.

Geological data from the National River Flow Archive[5] for four gauges in the catchment are presented in Figure 2-3. Bedrock permeability is reported to be very low in the upper catchment (Dee at Bala). Permeability increases down the catchment (between downstream gauges at Manley Hall, Ironbridge and Chester Suspension Bridge, just upstream of the River Dee's tidal limit). The BFIHOST[6] index is a measure of catchment responsiveness accounting for baseflow and soil type (indicating runoff) (Figure 2-3). Higher values are associated with higher groundwater contribution and/ or slower runoff rates and more resilient flow. Thus, as with increasing permeability down the catchment, the BFIHOST shows a greater groundwater contribution in the lower catchment than in the upper catchment.

[4] JACOBS (2013). B1867400 River Dee SSSI Restoration Management Report_Final.doc
[5] National Flow Archive https://nrfa.ceh.ac.uk/
[6] Measure of catchment responsiveness derived using the 29-class Hydrology Of Soil Types (HOST) classification.



Station (in order from most upstream to downstream)	BFIHOST
Bala	0.35
Manley Hall	0.43
Ironbridge	0.47
Chester Suspension bridge	0.47

Figure 2-3. Left: bedrock permeability class (%) for each gauging station in the Dee; Right: BFIHOST for each gauging station

2.3 Catchment Hydrology

The River Dee is a moderate to large sized river in terms of length and flow, and elevation is proportionally higher than most other similarly sized river systems with flow coming from the wet mountainous areas of Snowdonia. Flow is measured by NRW at four gauges in the catchment. Table 2-1 shows the catchment area and grid reference for each gauging station, in order from upstream to downstream, along the river.

Table 2-1. Catchment information from NRFA at gauging stations

River and location	Grid reference	Catchment area (km^2)
Dee at Bala	SH942357	262
Dee at Manley Hall	SJ348415	1,013
Dee at Ironbridge	SJ417600	1,674
Dee at Chester Suspension Bridge	SJ410659	1,817

Further information on these sites is provided in Figure 2-4 to Figure 2-7, in order from upstream to downstream.

Dee at Bala

- The record extends from 1970 to present.
- **Elevation** at the gauge is 157.5m AOD. Maximum altitude in the catchment is 878.2m AOD and median altitude is 377.0m AOD.
- **Mean Flow**: 13.1 m^3/s.
- Flood Attenuation by Reservoirs and Lakes (**FARL**) index is 0.84.
- Average annual rainfall (**SAAR 1961-1990**) is 1,844mm.

Flow Statistics	Full Record (m^3/s)
Q_{99}	1.5
Q_{95}	2.5
Q_{70}	5.6
Q_{50}	7.9
Q_{30}	14.0
Q_{15}	24.5
Q_{10}	29.8
Q_5	38.7

Flow time series at the site

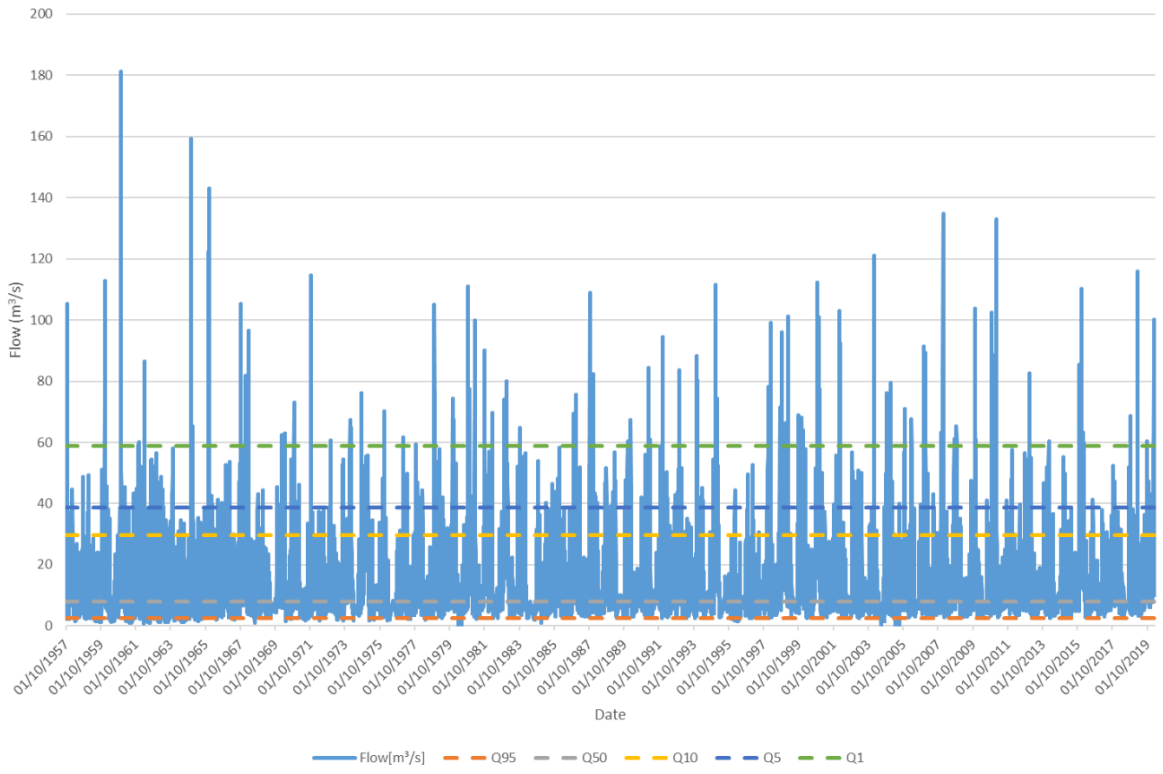


Figure 2-4. Hydrology information at Bala gauge station[7]

[7] National Flow Archive – Dee at Bala. https://nrfa.ceh.ac.uk/data/station/spatial/67001

Dee at Manley Hall

- The record extends from 1970 to present.
- **Elevation** at the gauge is 28.1m AOD. Maximum altitude in the catchment is 878.2m AOD and median altitude is 377.0m AOD.
- **Mean Flow**: 31.5 m^3/s.
- Flood Attenuation by Reservoirs and Lakes (**FARL**) index is 0.93.
- Average annual rainfall (**SAAR 1961-1990**) is 1,367mm.

Flow Statistics	Full Record (m^3/s)
Q_{99}	7.6
Q_{95}	8.5
Q_{70}	11.5
Q_{50}	19.5
Q_{30}	34.8
Q_{15}	57.1
Q_{10}	70.5
Q_5	93.1

Flow time series at the site

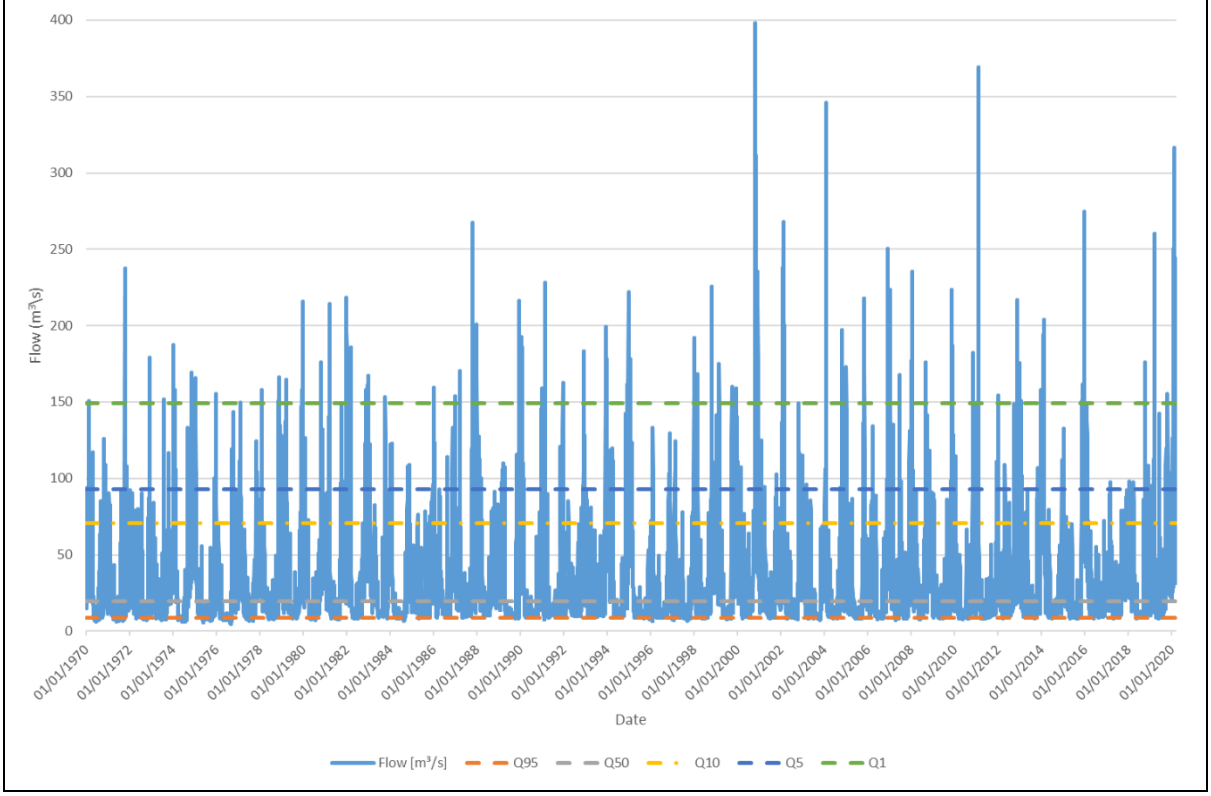


Figure 2-5. Hydrology information at Manley Hall gauge station[8]

[8] National Flow Archive – Dee at Manley Hall. https://nrfa.ceh.ac.uk/data/station/spatial/67015

Dee at Ironbridge

- The record extends from 1993 to present.
- **Elevation** at the gauge is 3.8m AOD. Maximum altitude in the catchment is 878.2m AOD and median altitude is 262.8m AOD.
- **Mean Flow**: 38.2 m^3/s.
- Flood Attenuation by Reservoirs and Lakes (**FARL**) index is 0.96.
- Average annual rainfall (**SAAR 1961-1990**) is 1,143mm.

Flow Statistics	Full Record (m^3/s)
Q_{99}	9.1
Q_{95}	9.7
Q_{70}	13.7
Q_{50}	22.8
Q_{30}	41.2
Q_{15}	73.8
Q_{10}	95.0
Q_5	124.1

Flow time series at the site

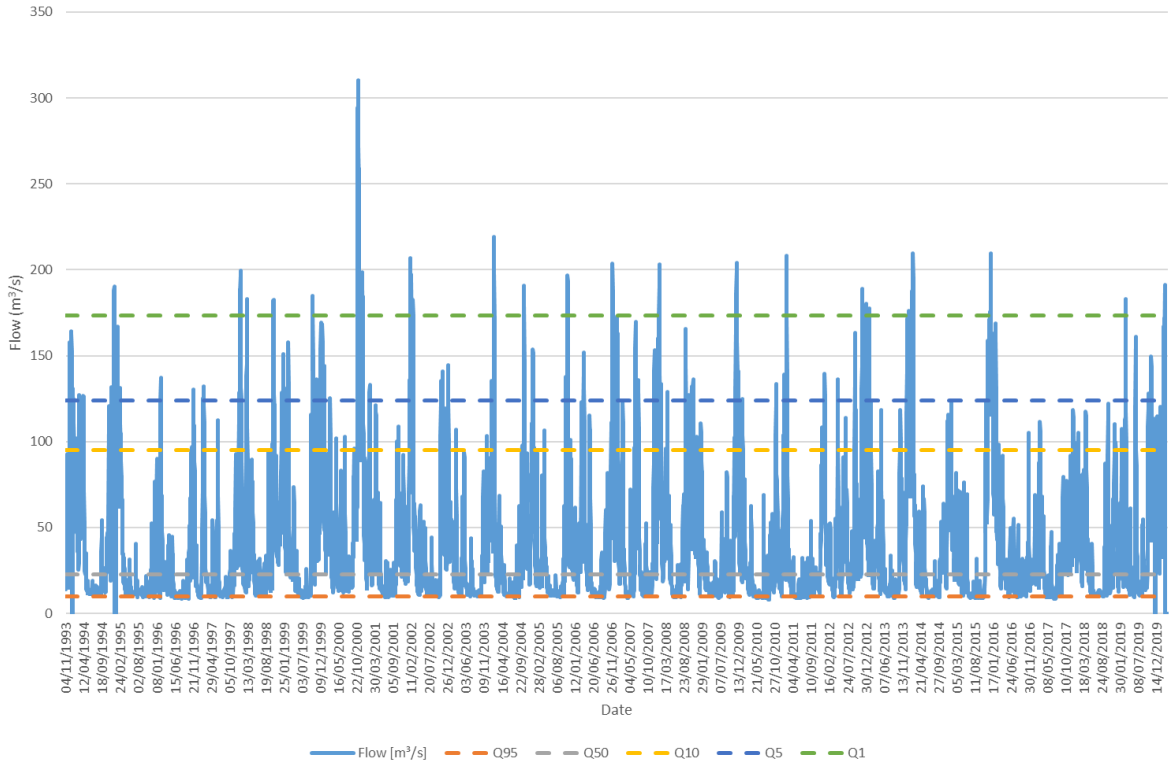


Figure 2-6. Hydrology information at Ironbridge gauge station[9]

[9] National Flow Archive – Dee at Ironbridge. https://nrfa.ceh.ac.uk/data/station/spatial/67027

Dee at Chester Suspension Bridge

- The record extends from 1994 to 2013.
- **Elevation** at the gauge is 2.6m AOD. Maximum altitude in the catchment is 878.2m AOD and median altitude is 241.9m AOD.
- **Mean Flow**: 33.7 m^3/s.
- Flood Attenuation by Reservoirs and Lakes (**FARL**) index is 0.96.
- Average annual rainfall (**SAAR 1961-1990**) is 1,110mm.

Flow Statistics	Full Record (m^3/s)
Q_{99}	4.5
Q_{95}	4.9
Q_{70}	9.0
Q_{50}	18.5
Q_{30}	37.5
Q_{15}	70.9
Q_{10}	91.0
Q_5	120.6

Flow time series at the site

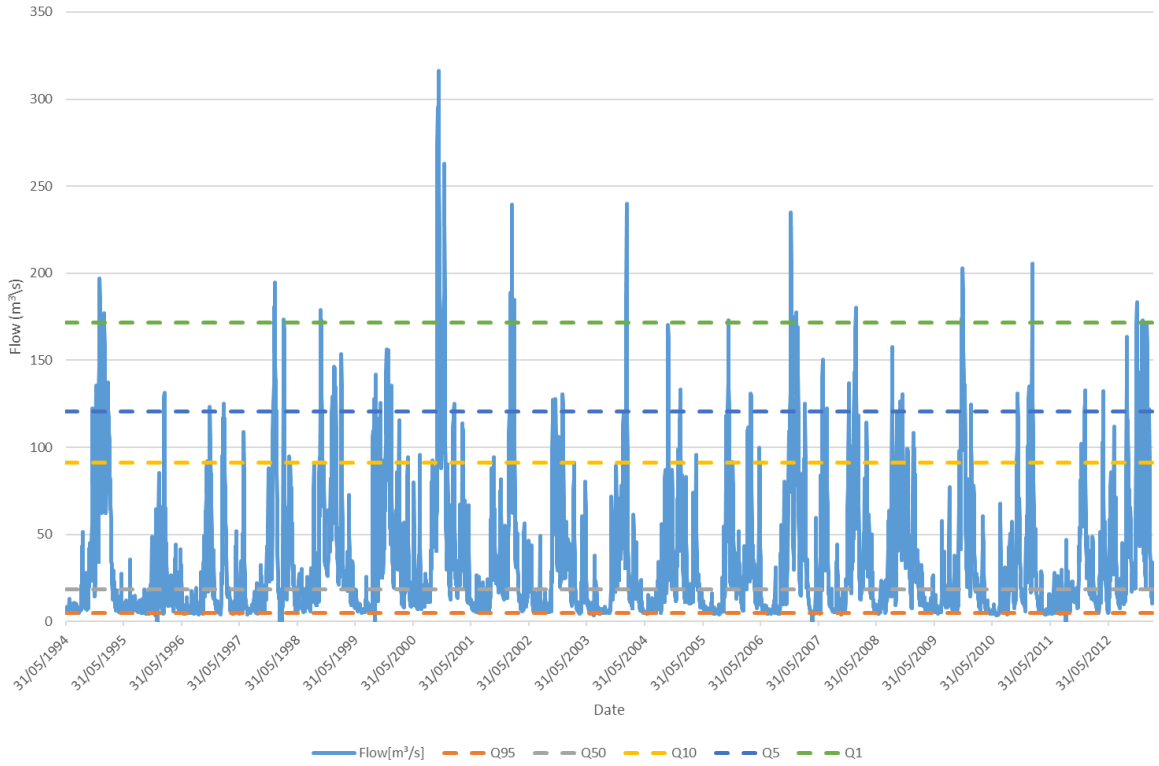


Figure 2-7. Hydrology information at Chester Suspension Bridge gauge station[10]

[10] National Flow Archive – Dee at Chester Suspension Bridge https://nrfa.ceh.ac.uk/data/station/spatial/67033

2.4 Designated Areas

River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid is a SAC and SSSI, designated for its internationally important river and lake system which supports excellent habitat for a number of protected and notable aquatic species, primarily Annex II species Atlantic salmon and floating water-plantain *Luronium natans*. Additional Annex II species supported by this site include river lamprey, sea lamprey, brook lamprey, bullhead and otter *Lutra lutra*. Local and non-statutory designations relevant to the six weirs are discussed in the relevant Sections.

3. Methodology

3.1 Overview

Broadly, development of the concept design for fish passage solutions at the six weirs on the River Dee has involved the following:

- Establishing the baseline, including undertaking surveys and desktop studies with regard to hydrology, ecology, hydromorphology, contaminated land, heritage and topography/ bathymetry;
- Undertaking hydraulic modelling and hydrological analyses to inform the design;
- Producing design schematics; and
- Producing design visualisations (where required).

During the project, members of the LIFEDeeRiver team have also engaged with stakeholders and landowners which has further informed the concept designs.

3.2 Establishing the Baseline

3.2.1 Flow Estimates at the Weirs

3.2.1.1 Typical Flows

Flow statistics for each of the weirs have been estimated, building on the catchment hydrology outlined in Section 2.3, for five of the weirs (Horseshoe Falls, Llangollen Upstream and Downstream, Erbistock, Chester), and using LowFlows software for the ungauged Morlas Brook. These were then used in the hydraulic modelling (Section 3.3).

The six weirs are outlined in Table 3-1 below along with information detailing the respective catchment sizes, closest flow gauging station and rationale for flow statistic estimates to be used. Flow estimates for the sites are provided in Table 3-2.

Table 3-1. Fish pass sites: Grid reference, catchment size and flow statistics estimation

Site	Grid Reference	Catchment size at fish pass[11] (km^2)	Flow statistic estimate for this gauge
Horseshoe	SJ1954143352	752.7	The site is reasonably close to the Manley Hall (River Dee) flow gauge and so statistics at the site can be estimated from the gauge
Llangollen Upstream	SJ2136742132	785.4	The site is reasonably close to the Manley Hall (River Dee) flow gauge and so statistics at the site can be estimated from the gauge
Llangollen Downstream	SJ2159442108	785.8	The site is close to the upstream weir and those values estimated for that site will be used here.
Morlas	SJ3119038319	21.1	Flow statistics to be determined through LowFlow Estimate software
Erbistock	SJ3544442161	1,033.5	The site is close to the Manley Hall (River Dee) flow gauge and so statistics at the site can be estimated from the gauge
Chester	SJ4082365854	1,801.0 (site is actually downstream of the gauge though catchment size reported by FEH is lower than that reported at the gauge on the NRFA)	This site is very close to the gauge and the statistics essentially apply to this site too.

[11] UK Centre for Ecology and Hydrology. Flood Estimation Handbook - https://fehweb.ceh.ac.uk/GB/map

Table 3-2. Flow (statistic) estimates for each fish pass site

Flow Statistic	Flow at Fish Pass sites (m^3/s)					
	Horseshoe Falls	Llangollen Upstream	Llangollen Downstream	Morlas (from LowFlow software)	Erbistock	Chester
Q_{99}	5.6	5.9	5.9	0.04	7.7	4.5
Q_{95}	6.3	6.6	6.6	0.06	8.7	4.9
Q_{70}	8.6	8.9	8.9	0.12	11.8	9.0
Q_{50}	14.5	15.1	15.1	0.19	19.9	18.5
Q_{30}	25.9	27.0	27.0	0.32	35.5	37.5
Q_{15}	42.4	44.2	44.2	0.56	58.2	70.9
Q_{10}	52.4	54.7	54.7	0.74	72.0	91.0
Q_5	69.1	72.1	72.1	1.06	94.9	120.6

3.2.1.2 Flood Flows

Flood flows for each of the weirs have been estimated for 1 in 2 year and 1 in 100 year plus 30% Climate Change return periods.

In agreement with NRW, return periods and flood flows were output by the Flood Estimation Handbook (FEH) software. This method was chosen due to the catchment and associated sites are applicable with the approaches. Further details on flood estimation derivation is detailed in Appendix A. In the case of Morlas, due to the hydraulic model encompassing two watercourses, this method was applied at Afon Morlas to get the flood inflows for this watercourse. Flood inputs at Afon Ceiriog watercourse were subsequently calculated through catchment apportioning, acknowledging the relative catchment sizes. Flood peaks for 1 in 2 year and 1 in 100 year plus 30% climate change event hydrographs for each weir are shown in Table 3-3 below.

Table 3-3. Flood peak (m^3/s) for required return periods for each fish pass site

Location and Model	1 in 2 year peak flow (m^3/s)	1 in 100 year plus 30% CC peak flow (m^3/s)
Horseshoe Falls	191.1	518.5
Llangollen Upstream and Downstream	193.9	526.1
Morlas Brook (Afon Morlas)	5.1	21.5
Morlas Brook (Afon Ceiriog)	27.8	117.1
Erbistock	228.8	663.1
Chester	268.0	682.5

3.2.2 Geomorphological Assessment and Audit

River flows and geomorphological processes are highly regulated throughout the River Dee, including by the six weirs under assessment in this project. Without these controls, the river would be more likely to actively meander by eroding across its floodplain, but with these weirs and other structures the channel is in a broadly fixed position at all study sites[12]. On the basis of previous studies, geomorphological assessments and audits were limited to re-surveys at 5 weirs (Horseshoe Falls, Llangollen Upstream and Downstream, Morlas and Erbistock), extending 250 m upstream and 500 m downstream. Site visits were undertaken on 16 - 17 July 2020 during baseflow conditions despite some moderate rainfall across the catchment in the preceding week, and used to document river conditions and geomorphological risks with regards to preferred options.

The desk-based component of the audit included a review of historic maps and aerial imagery. This allowed key locations susceptible to avulsion on the short to medium term to be confirmed and

[12] Hill, C.T. and Emery, J.C. (2005) Fluvial Audit of the River Dee, Report UC0690, GeoData Institute

identified again building on the work of Hill and Emery (2004)[13]. Some key findings of this study are summarised below:

- Analysis of historical map records suggest the study reach has been relatively stable over the last 115 years, with only a small subset of sections showing consistent channel migration. No channel changes exceeded two channel widths and although there are localised changes these are small scale and geographically limited. In themselves these change locations provide physical and habitat diversity;
- Palaeochannels in the floodplain indicate a more dynamic river in the past. Extensive flow regulation in the Dee catchment since the 1900s may be a factor;
- The dominant bank material is alluvial sand and silt throughout the study length, although there is an increase in the coarse fraction from zone 1 to zone 3 (Erbistock, Llangollen, Horseshoe and Morlas) (with significant bedrock control through the Llangollen gorge section);
- The dominant bed materials are coarse gravel and cobbles with the exception of zone 4a (Chester), which is predominantly fines or obscured by the greater flow depths. Bed sediment calibre increases downstream from zone 1 to zone 3 (Erbistock, Llangollen, Horseshoe and Morlas);
- Glide, pool-riffle and run are the dominant flow biotopes throughout the Dee, and, as suggested by the coarser bed material, zones 1 to 3 (Erbistock, Llangollen, Horseshoe and Morlas) have the largest proportion of faster flow types, whilst zone 4 and 4a (Chester) are predominantly glide[14].

Hydraulic model outputs have been examined as needed (e.g. with regard to local stream power and/or bed shear stress) to determine the potential for the sites to erode and/or deposit upstream/downstream or outflank a structure following modification etc.

3.2.3 Preliminary Ecological Appraisal (PEA)

Compliant with the Guidelines for Preliminary Ecological Appraisal (PEA) published by the Chartered Institute of Ecology and Environmental Management[15], a PEA was be completed for Horseshoe Falls, Erbistock and Chester weirs. Each PEA included a desktop study to collate details of international statutory designated sites within a 10 km radius, other statutory and non-statutory designated sites within a 2 km radius and records of legally protected and other notable species including invasive non-native species (INNS) within a 1 km radius. In addition, two surveyors (one freshwater and one terrestrial specialist) undertook an extended Phase 1 Habitat Survey (PHS) at each site. Habitats present were classified according to the PHS methodology[16], and an initial assessment of the potential for habitats within each Site to support legally protected and/or notable species including any scheduled INNS was undertaken. The area of interest at each Site included the location of proposed in-channel works and the immediate bankside and adjoining terrestrial habitats that could potentially be impacted by associated construction works. Each PEA considered potential ecological constraints and opportunities that could arise from the proposed works, and recommended further surveys where required.

3.2.4 Contaminated Land Preliminary Risk Assessment (PRA)

A contaminated land Preliminary Risk Assessment (PRA) was prepared for all six weirs, comprising a high level tabular/ qualitative desk-study report. Reporting followed recommended best practice outlined in the Environment Agency (EA)'s Land Contamination: Risk Management Guidance (2019) and the British Standards (BS) 10175 and BS 5930. Information reviewed included: (i) a Groundsure report for each site (including historical maps and environmental database information); (ii) published information on ground conditions/ geology, British Geological Survey borehole logs, hydrogeology (including groundwater vulnerability) and hydrology; iii) any existing information held by NRW. A

[13] Hill, C. and Emery, J. (2004), *'Fluvial Audit of the River Dee'*
[14] Hill C.T. and Emery J.C. (2005) Fluvial Audit of the River Dee, Report UC0690, GeoData Institute
[15] CIEEM (2017) Guidelines for Preliminary Ecological Appraisal, 2nd edition. Chartered Institute of Ecology and Environmental Management, Winchester.
[16] Joint Nature Conservation Committee (2010) *Handbook for Phase 1 Habitat Survey: A Technique for Environmental Audit*. Joint Nature Conservancy Committee: Peterborough.

Conceptual Model and (Qualitative) PRA were produced, giving preliminary consideration to design implications of the proposed works and identifying any need for intrusive ground investigation and remediation works.

3.2.5 Heritage Assessments

High level heritage assessments were undertaken at Llangollen Upstream, Llangollen Downstream and Morlas weirs. A search radius of 500m around each weir was applied to identify any designated assets including Scheduled Monuments, Listed Buildings and Conservation Areas, and to appraise any non-designated assets to develop a broad understanding of the site archaeology. Historical maps were also reviewed to identify key changes and inform the assessments.

Detailed heritage assessments were carried out at Horseshoe Falls, Erbistock and Chester weirs. These were informed by walkover surveys and further desk-based research on available historical documentary, cartographic and pictorial information, and previous archaeological and geotechnical reports. A number of sources were consulted for the study, including: relevant historic environmental records and archives; local studies services; National Monuments Record of Wales; information supplied by NRW, and; Cadw List of Buildings of Special Architectural or Historic Interest. The information collected was used to describe the cultural heritage resource of a defined study area (~1 km radius, subject to Welsh Archaeological Trust and Cadw consultation) to gain an understanding of surrounding area's historic nature.

3.2.6 Topographic and Bathymetric Surveys

Topographic surveys were undertaken at all six weirs in accordance with EA National Survey Specification Guidance v3.2[17] by wading or boat using total station and detail pole coordinated by GNSS to OSGB 1936 grid and datum. Specifically, the following surveys were conducted:

- Weir structure topographic survey at all six weirs;
- Survey of the ground and riverbed immediately around each weir, extending 10m upstream of the crest of the weir, 10m downstream of the toe of the weir, and 10m into the bank (away from the river);
- River section surveys at all six sites, undertaken at 10m intervals, up to a distance of 50m upstream and downstream of each weir. Sections were then recorded at intervals of 50m from 50m to 400m upstream and downstream of each weir (with the exception of Erbistock weir in which the most upstream section was *c*. 600m upstream of the site but with the same number of cross sections evenly distributed over the distance). Bank top levels (either channel wall to road level, raised wall, embankment or natural ground) were also recorded for each river section; and
- Surveys of the leat/ side channels at Horseshoe Falls, Erbistock and Chester weirs. Cross-sections were undertaken at the upstream and downstream extents of the side channels (i.e. at the upstream extent within a distance of 5m from the inlet to the channel, and at the downstream extent within 5m of the reconnection with the main river, or where it joins existing ground level). Cross sections were also undertaken at 10m intervals throughout the channels, so that the side channels comprise a minimum of four survey sections. If the side channel was less than 20m in length, a minimum of two evenly spaced cross sections were undertaken.

Data were used for hydraulic modelling at each weir (Section 3.3.1).

3.2.7 Services Search

A services search for gas, electric, water, sewage and British Telecom was obtained through Groundsure for all six weirs, allowing informed site surveys to take place and concept design of the preferred option at each site to be undertaken with site-specific constraints in mind. Service plans were drafted for each of the six weir sites and are presented in the respective report Sections. It should be noted that the utilities reports provided by Groundsure are intended to be for project planning and feasibility only, and should not be used for construction or excavation purposes.

[17] Environment Agency (2013) National Standard Contract and Specification for Surveying Services v3.2, https://www.channelcoast.org/ccoresources/specificationsandbriefs/EA_Nat_Survey_Specs_V3.2.pdf

3.3 Design

3.3.1 Hydraulic Design and Fish Passage Review

Hydraulic modelling was undertaken to inform the outline design of the fish pass recommended options at each site. Specifically, modelling has been undertaken to ascertain if the hydraulic design of preferred options would allow passage for species of interest (Atlantic salmon, sea, river and brook lamprey, bullhead, sea trout, eel) throughout the interannual ('typical') flow ranges required[18].

Fish passage is required during typical flows, ranging between low (e.g. Q_{95}) through to high (e.g. Q_{10}) flows. The focus of the study was on examining the hydraulics under this range, hence a 2D modelling approach was taken, using TuFlow. The typical flow hydrology, as outlined in Section 2.3, was accounted for in the modelling of Q_{95}, Q_{50} and Q_{10} scenarios (of the baseline situation and options). Results of those scenarios were examined with regard to the following, to assess compliance with best practice guidelines[18]:

- Design velocities in relation to fish species swimming abilities;
- Design depths in relation to species requirements;
- Volumetric energy dissipation;
- Entrance attraction flow in terms of discharge volume, plume characteristics and location;
- Entrance and within-structure hydraulic functionality relating to fish behaviour;
- Any requirement for resting pools to ensure uninterrupted fish pass lengths are within relevant sustained and burst swimming capabilities.

Velocity criteria for a notch fish pass are provided in Table 3-4 below[18]. Similar criteria can be applied to partial weir removals where increased velocities occur only in the vicinity of the area of removal, noting that streaming, rather than plunging, flow conditions would occur throughout Q_{95} - Q_{10} flows.

Table 3-4. Maximum velocity and head drop requirements for a notch weir modification for various fish species[18]

Species	Max Velocity (m/s)	Head Drop (m)
Salmon	3.00-3.40	0.45-0.60
Sea Trout	2.40-3.00	0.30-0.45
Brown Trout	1.70-2.40	0.15-0.30
Coarse Fish	1.40-2.00	0.10-0.20

Full weir removals and nature-like bypasses should take into consideration sustained (maintained for ≥200 minutes) and burst (maintained for ≥20 seconds) swimming speeds and depth requirements of the target species[18]. Near-natural nature-like bypasses should also ensure that channel gradient is low (≤2.5%)[18].

In addition to fish passage assessment, flood scenario runs were undertaken to examine if there were any potentially significant issues associated with the proposed options, e.g. excessive uncontrolled channel re-adjustment following weir removal. Flood flow estimates for each site were calculated as outlined in Appendix A. Reviewed flood run outputs including depth, velocity and bed shear stress were investigated to inform mitigation measures within the concept design (e.g. where high energy levels from uncontrolled full or partial weir removal pose unacceptable risk to local receptors without mitigation).

Bespoke 2D site hydraulic models were built for each site using freely available NRW LiDAR data, topographic and bathymetric data obtained for this study (see Section 3.2.6), and topographic and hydrological information described above.

[18] Armstrong, G.S., Aprahamian, M.W., Fewings, G.A., Gough, P.J., Reader, N.A. and Varallo, P.V., 2010. Environment Agency Fish Pass Manual: Guidance notes on the legislation, selection and approval of fish passes in England and Wales. Environment Agency, Rio House, Bristol http://publications. environment-agency. gov.uk.

3.3.2 Water Level Analyses

At some sites, proposed fish pass options are small scale and / or would require water that would otherwise flow elsewhere including over the weir and significant changes in this would be considered adverse. At these sites, additional empirical analyses for water balances were undertaken to help inform the optioneering/ suitability of options.

3.3.3 Design Schematics

Design schematics have been produced, to include the following: a plan of the works (including known utilities, potential access routes and constraints); indicative cross (up to three) and long (one) sections for naturalised fish pass options (e.g. removal or bypass channels); concept design information on technical fish passes (including invert levels and confirming performance as required to enable fish passage) noting that much of this, including precise locations, would be confirmed during detailed design.

3.3.4 Design Visualisations

Visualisations will be provided by our landscape team, demonstrating the potential appearance of the final schemes to inform public and stakeholder consultation for Horseshoe Falls, Llangollen Upstream and Downstream and Chester.

4. Erbistock Weir

4.1 Baseline

4.1.1 Site

Erbistock weir is associated with a historical mill that was once a listed structure. The building is functional and used for holiday lets, but is no longer used for milling. There are other buildings close by that are still be listed, located approximately 450m north-west, 375m north and 150m to the south-west of the Site.

The site is situated on the River Dee in north-east Wales, approximately 700m north of Erbistock on the east side of a road running south off the A528 from Overton Bridge. The weir is centred on NGR SJ 35446 42164.

A mill leat channel is located between the building and the weir. A water wheel is present in the leat channel but does not currently function. The weir is a steep stone-faced weir approximately 2.5m high and 70m wide placed at an angle to the flow as it exits a bend in the river. An existing baulk fish pass and modified sloped concrete apron is located on the RHB of the weir. There is a breach in the downstream face of the weir that reportedly occurred in 2019.

At project onset the preferred option was partial removal to bed level of approximately 30% of the weir (central section removed) and to maintain the remaining section of the weir structure on the left bank for the landowner. The removal may be extended to the failed section of the weir (leaving approximately 30% of the weir width intact) following further discussions with the landowner.

4.1.2 Site Visit

The site was visited on the 17 July 2020. Images from this are presented in Plates 8-1 through to 8-25. The hydromorphology of the site is discussed further in Section 4.1.4 and was informed by the site visit.

Plate 8-1. River Dee downstream of the weir (from LHB)

Plate 8-2. Erbistock weir from downstream of rental building (LHB)

Plate 8-3. Invasive species, LHB downstream of weir

Plate 8-4. River Dee downstream of the weir (from LHB)

Plate 8-5. River Dee downstream of the weir (from LHB)

Plate 8-6. River Dee downstream of the weir (from LHB) looking downstream

Plate 8-7. Residential property decking beside the river. Leat channel wheel also apparent

Plate 8-8. River Dee downstream of the weir (looking downstream/ from LHB sediment deposit)

Plate 8-9. Erbistock weir from LHB

Plate 8-10. River Dee downstream of the weir (from LHB)

Plate 8-11. LHB side and bottom end of weir, showing dilapidation

Plate 8-12. Erbistoch weir from downstream LHB

Plate 8-13. RHB side of weir from concrete apron on RHB side

Plate 8-14. Erbistoch weir from concrete apron on RHB side

Plate 8-15. Broken up section toward the LHB side of the weir

Plate 8-16. Erbistock weir from concrete apron on RHB side

Plate 8-17. Wheel above leat channel

Plate 8-18. Residential property (LHB at weir)

Plate 8-19. River Dee upstream of the weir (from LHB)

Plate 8-20. River Dee upstream of the weir (from LHB)

Plate 8-21. Gravel deposit LHB/ approximately 600m upstream of the weir

Plate 8-22. Gravel deposit LHB/ approximately 600m upstream of the weir

Plate 8-23. Channel beside gravel deposit (mildly turbid)

Plate 8-24. River Dee looking upstream from the gravel deposit

Plate 8-25. River Dee looking upstream from the gravel deposit

During the visit NRW advised us of, or we could observe, the following:

- The weir is in a poor condition with parts of it notably disintegrated, e.g. as indicated in Plate 8-15.
- An estates rental building (former mill) is located on the left-hand bank and neighbouring the weir. We were advised that this area flooded in February / March 2020 with flows going over the decking and back into the river downstream.
- In the same area there is a leat to the mill with a redundant water wheel (Plates 8-7 and 8-17). The estate have requested that this is sealed up as part of the design. To date, the estate have already undertaken some work to achieve this but some flow still gets through.
- On the right-hand bank there is an existing baulk fish pass which isn't achieving fish passage. There is a sloped concrete apron between the existing fish pass and the right-hand bank.

- Tenant famers operate the farms on the right-hand bank side (owned by the estate).
- Partial removal of the weir is proposed, leaving a small section beside the property. The estate want to maintain some of the weir structure and propose that removal is completed along the section from the broken up area indicated in Plate 8-15 through to the right-hand bank concrete apron. The concrete apron would be retained.
- NRW confirmed to the estate owners that they would take responsibility for the site through the works, but management of the structure would return to the owners on completion of construction.

Following the site visit some photos of the weir were provided to us by NRW, taken when the flow was diverted away from the right-hand bank side of the structure. Some of these are provided in Plates 8-26 to 8-29, and show that much of the weir and existing fish pass are in a poor condition.

Plate 8-26. Poor condition of the weir, looking from the RHB concrete apron

Plate 8-27. Poor condition of the weir including the baulk fish pass, looking from the RHB concrete apron

Plate 8-28. Poor condition of the weir including the collapsed section, looking from the RHB downstream of the weir

Plate 8-29. Poor condition of the structure, looking across the weir from RHB concrete apron

4.1.3 Water Framework Directive

Erbistock weir lies within the Chester Weir to Ceiriog WFD surface water body (GB111067057080) which is reported as having a 2016 Moderate Overall and Ecological Rating while its and Chemical Rating is Fail due to contamination with Polycyclic Aromatic Hydrocarbons (PAHs). The study area is within the Dee carboniferous coal measures Ground waterbody (GB41102G204800), which has an overall 2016 status of Poor whilst chemical status is Poor and quantitative status is Good.

4.1.4 Hydromorphology and Historic River Character

In historic mapping, a weir is present on site in the same location as the present-day weir. In the same map, a flour mill is also recorded on the right-hand bank of the river near the western site boundary, adjacent to the weir, that would have impounded water to power the flour mill.

Erbistock weir is a large structure, approximately 2.5m in height and located 65m from a derelict millleat and water wheel on the left-hand bank to a poorly functioning baulk fish pass against the

RHB. The size of the weir means it directly and severely impacts approximately 1km of flow and sediment patterns around the structure, while impacts on the continuity of fish passage upstream, and sediment habitats downstream, propagate much more extensively along the river.

The River Dee in the vicinity of Erbistock weir is a single thread, meandering channel flowing through a wide and shallow valley. The watercourse is set in extensive alluvial deposits succeeding glacio-fluvial till and terraces. Underlying bedrock is Salop formation mudstone, sandstone and conglomerate. Superficial deposits appear (on the basis of site visits) to be more extensive than geological maps suggest and are probably continuous along the valley around Erbistock but are obscured in the vicinity of the weir due to impoundment and submergence, and are therefore un-mapped.

Bedrock is likely to be near the surface, and forms the sharp ridge running north-south which falls some 15 - 20m to the east of the village of Erbistock. The valley narrows south of Erbistock as a result of this outcrop, before opening into a wide terrace plane towards Owrtyn and reversing direction back to the west and Erbistock weir, before encountering the same outcrop ridge that narrows the valley again to form a natural constraint and sharp drop in elevation on which the weir is located. Geophysical surveys such as ground penetrating radar will be needed to properly understand the depth of substrate to solid bedrock. The north bank of the Dee immediately upstream of the weir has been built up, reinforced and straightened to augment this natural constraint and increase the head drop at the weir. Erbistock Mill and water wheel are located on the opposite bank but the mill leat is now disused and partially blocked at the headward end. Downstream, the river flows north, then the valley floor opens into a lowland plane past Bangor-is-y-coed and Wrexham, with a characteristic tightly meandering river.

Palaeochannels are evident in aerial imagery up and downstream of Erbistock weir suggesting that the unmodified watercourse would have been characterised by an active meandering typology that has moved laterally across the wide, open floodplain in the post-Pleistocene epoch. The bedrock constraints probably mean the river position is fixed immediately north and south of Erbistock, but throughout the Holocene the easterly meander loop has migrated across the open valley floor extending towards Owrtyn, and eroded a large volume of coarse fluvio-glacial deposits into the river system, which would have formed high quality fish habitats. The channel morphology would have been characterised by repeating pool and riffle sequences with gravel bars, all coupled with varying flow habitats, probably with multiple channels. These dynamics will be suppressed and submerged in the impounded reach, but could be re-exposed and reactivated if the weir is removed or modified.

The watercourse is impounded for 600m upstream of the weir to the area of Groves Farm, and the flow regime through this reach is dominated by slow moving gliding flow with no variation (see Plate 8-20). The weir acts as a barrier to sediment continuity and as a result the reach upstream is a major sediment sink, to the detriment of river continuity and habitats downstream. Upstream of the impounded reach coarse gravel is visible in the channel and a medium to large mid channel bar exists at the same location as recorded in the 2005 fluvial audit.

Downstream of the weir coarse material has formed a large lateral bar on the left bank, a smaller more submerged bar adjacent to the right bank, and a transverse riffle across the channel as it bends left. These bed features seem to be derived mainly from material that existed at this location prior to the weir, and a large scour pool that has developed at the foot of the weir. Some coarse material may carry over the weir by saltation in flood events, but the bed upstream has not aggraded to a level flush with the weir crest, so the majority of the bedload, which moves by traction, will be trapped. Fine sediment will carry over the weir relatively easily in suspension, so as well as trapping habitat-forming coarse substrates, the weir will contribute to disproportionately high fine sediment loads downstream. A lot of that fine sediment is likely to be derived from the catchment surface and extensive agriculture on the lowland alluvium. Flows return to uniform glide a short distance downstream of the weir, which is further evidence of coarse sediment trapping, and presumably further modifications downstream.

4.1.5 Contaminated Land PRA

A contaminated land PRA was undertaken for Erbistock weir and is included in Appendix B. Key conclusions, implications and recommendations from this are reproduced in Table 4-1 below.

Table 4-1. Erbistock weir removal PRA findings

Conclusion	Design Implications	Recommendations
The desk study identified that: • Published Geology of the site and the Groundsure reports indicate that the majority of the site is not underlain by Superficial deposits, with Alluvium present in the north west corner of the site which is classed as a Secondary A Aquifer. Bedrock deposits are formed of the Salop Formation and are classed as a Secondary A Aquifer. It is noted that there are likely to be bed sediments up and down stream of the weir. • On site ground setting is unknown due to the absence of exploratory locations in the area. • On site soils are described as having high leachability. • The site is in an area subject to high risk of flooding, as would be expected for a riverine site. • Historic land use on and surrounding the site could contribute to environmental impacts.	On site ground setting is unknown and therefore conditions for working access are not known, especially if access is required from the south east. State of surface water quality is not known and therefore the impacts of sediment release on the downstream environment cannot be assessed. The chemical status of the sediment is not known and hence the possible waste classification is unclear which may present cost implications if sediments need to be removed from site.	Sediment sampling and analysis should be carried out from locations within the vicinity of the proposed works. Samples should be assessed for particle size distribution and, assuming fine material is present, chemically tested to determine the presence and concentrations of Chemicals of Potential Concern (CoPCs) associated with these historic land uses. Due to historic flooding events recorded on the site, it is possible that fine sediment has been moved, which may have reduced the risk of mobilising contaminated sediment during the works. The information obtained here will aid the reassessment of pollutant linkages. Surface water samples should be taken on the River Dee running through the site. Surface water should be collected at one to two locations on site. This will enable a baseline to be established, as well as giving insight to presence and concentrations of CoPCs. Upon completion of the works and bed regrading, samples should be taken from the new interface between the sediment and the overlying water column to verify that levels of contamination are within the range detected during the baseline assessment. The presence of potentially contaminated sediments behind the weir may not under current circumstances present a risk to human health and the aquatic environment. This risk status could change due to the partial weir removal works. Depending on the results of the ground investigation, mitigation measures may be required to manage these risk and these could include excavating and removing sediments, with waste classification and appropriate treatment / disposal, or capping sediments during the works. Due to the sensitive nature of the site, which is located within a SSSI and SAC, a conservative approach may be recommended to mitigate any potential long-term impacts, such as those associated with transport and deposition and / or increased erosion, which can be difficult to predict. It is recommended that appropriate geotechnical assessment is carried out prior to any works in order to access the suitability of access for plant and the stability of the weir. Sediment samples should also be classified for waste disposal designation and the potential costs associated with the this. There is the potential to explore the deposition of sediments in the vicinity of the weir subject to regulatory agreement. Appropriate heritage assessments should be carried out before any intrusive works are conducted, if not already conducted (see Section 4.1.7).

4.1.6 Ecology

4.1.6.1 Overview

A PEA was undertaken at Erbistock weir (Appendix C). Key details are outlined below.

4.1.6.2 Designated Sites

International Statutory Designated Sites

There are three international statutory designated sites within 10km of Erbistock weir, listed in descending order, with those closest to the Scheme listed first as summarised in Table 4-2 below.

Table 4-2. Sites with international statutory designations within 10km of Erbistock weir

Site Name	Designation	Description	Distance and Bearing from site
River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid	Special Area of Conservation (Wales) and Special Area of Conservation (England)	Internationally important river and lake system which supports excellent habitat for a number of protected and notable aquatic species, primarily Annex II species Atlantic salmon *Salmo salar*, Floating water-plantain *Luronium natans*. Additional Annex II species supported by this site include River lamprey *Lampetra fluviatilis*, Sea lamprey *Petromyzon marinus,* Brook lamprey *Lampetra planeri*, bullhead *Cottus gobio* and Otter *Lutra lutra.*	0m
Johnstown Newt Sites	Special Areas of Conservation (Wales)	Situated near Wrexham in the North East of Wales, this site is composed of two post-industrial sites previously used for coal and clay extraction. This site is designated as the natural water-filled hollows and mining subsidence ponds support breeding sites for one the largest known populations of Great crested newt *Triturus cristatus* in Great Britain.	5.4km NW
Midland Meres & Mosses Phase 2 (Wales)	Ramsar Site (Wales) and Ramsar Site (England)	The Midlands Meres and Mosses Phase 2 Ramsar Sites are a series of 18 water bodies (meres) which are nutrient-rich with fringing habitats of reed swamp, fen, carr and damp pasture, and peatlands.	10km SE

Source: MAGIC; Cofnod (Accessed 14/05/20)

National Statutory Designated Sites

There is one national statutory designated site within 2km of Erbistock weir, summarised in Table 4-3.

Table 4-3. Sites with national statutory designations within 2km of Erbistock weir

Site Name	Designation	Description	Distance
Afon Dyfrdwy (River Dee)	Sites of Special Scientific Interest (Wales) and Site of Special Scientific Interest (England)	Internationally important river and lake system which supports excellent habitat for a number of protected and notable aquatic species, primarily Annex II species Atlantic salmon *Salmo salar*, Floating water-plantain *Luronium natans*. Additional Annex II species supported by this site include River lamprey *Lampetra fluviatilis*, Sea lamprey *Petromyzon marinus,* Brook lamprey *Lampetra planeri*, bullhead *Cottus gobio* and Otter *Lutra lutra.*	0m

Source: MAGIC; Cofnod (Accessed 14/05/20)

Non-statutory Designated Sites

The operational catchment of the Lower Dee from Chester Weir to Ceiriog is designated as a Drinking Water Protected Area (Surface Water). There are also ten Local Wildlife Sites (LWS) within 2km of the site, the details of which are outlined in Table 4-4 below, listed in descending order, with those closest to the Scheme listed first.

Table 4-4. Non-statutory designated sites within 2 km of Erbistock weir

Site Name	Designation	Distance and Bearing from site
Dee – Chester Weir to Ceirog	Drinking Water Protected Area (Surface Water) (England)	0m
Palla Wood	Local Wildlife Site	100m NW
Neile's Wood	Local Wildlife Site	120m E
Manley Wood	Local Wildlife Site	720m SW
Llan-y-Cefn	Local Wildlife Site	900m S
Drury's Plantation	Local Wildlife Site	1,050m NW
Nanterral Wood	Local Wildlife Site	1,190m W
Dee Banks Wood	Local Wildlife Site	1,260m NE
Lower Farm Wood	Local Wildlife Site	1,570m SW
Long Wood and Grassland, Erbistock	Local Wildlife Site	1,580m NW
Eyton Hall Wood	Local Wildlife Site	1,780m N

Source: MAGIC; Cofnod (Accessed 14/05/20)

4.1.6.3 Ecological Findings of the PEA

The following key findings were determined during the PEA:

- The Scheme is located within the River Dee and Bala Lake SAC, which is designated for aquatic habitats and species, and is also designated as SSSI. It is not considered that there will be any adverse impacts on the SAC/SSSI; however, the relevant statutory bodies should be consulted to undertake Habitats Regulations Assessment screening, to determine whether the Scheme requires Appropriate Assessment;
- The habitats present at the site include running water and semi-natural broadleaved woodland, both of which are of high ecological value. Impacts to these habitats should be minimised and habitats reinstated to a similar condition upon completion of the works. The woodland on the right bank is connected to an area of ancient woodland (Morris Wood / Neile's Wood) approximately 120m east of the weir and impacts to ancient woodland should be avoided; and
- Access for construction is proposed via the arable field above the right bank, so it should be feasible to avoid impacts to the adjacent woodland. The arable field should also be utilised for the

site compound area, where required and with permission of the landowner, to avoid further impacts to woodland.

4.1.6.4 Key Ecological Receptors and Further Considerations

The following ecological receptors have been identified as present or potentially present in the area of the Scheme:

- River Dee is a Habitat of Principal Importance;
- Ancient Woodland within 1km of the weir 110m NW, Palla Wood (30612) to western side of the valley road; 120m E, Morris Wood / Neile's Wood (30611);
- River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid SAC;
- Afon Dyfrdwy (River Dee) SSSI;
- Birds (full list of species in Appendix C);
- Flowering plants (bluebell);
- Insects (Caddis Fly (Trichoptera), Mayfly (Ephemeroptera), Stonefly (Plecoptera));
- Molluscs (freshwater pearl mussel);
- Water vole;
- Hedgehog;
- Otter;
- Badger;
- Bats;
- Fish (Atlantic salmon, brown trout, European eel, lamprey sp., bullhead); and
- INNS (Japanese knotweed, Himalayan balsam).

These ecological features may constrain implementation of the Scheme and should be considered further when planning and implementing site works. In the case of the identified species, these have potential, if present, to be key constraints that will require specific consideration and action to avoid conflicts with, and potential breaches of, relevant nature conservation legislation. Where potential ecological risks are identified, their actual presence / absence would need to be determined through specialist surveys at the appropriate time of year.

Further surveys recommended before construction include:

- Roosting bats - Due to the proposal to coppice trees on the right bank for site access adjacent to the weir and upstream within the drawdown reach, a Preliminary Roost Assessment (PRA) of these trees for their potential to support roosting bats should be completed once trees requiring removal or coppicing are identified. The surveys will also identify any further surveys required for roosting bats and subsequent licensing.
- Nesting birds - The woodland on the right bank, and the right bank itself in terms of kingfisher and dipper, are of high value habitat for nesting birds. The proposals include the removal and/or coppicing of trees on the right bank, and therefore further investigation will be required for nesting birds, should vegetation clearance be carried out in the main bird nesting season of March to September. A check for nesting birds must be undertaken prior to clearing vegetation (trees and scrub) between April and September. If an active nest is found, works shall not be undertaken in close proximity to the nest site. A suitable buffer zone would be demarcated around the nesting site (as determined by the supervising ecologist) until such time as all the eggs have hatched and the young birds fledged and left the nest.
- Otter and water vole - Pre-works check for otter, which are well established in this area of the River (and water vole in the unlikely event that they are present), including upstream beyond the current survey area in the drawdown reach, should be completed by a suitably qualified ecologist. The pre-works check will inform the requirement for additional mitigation in relation to these species.
- Badger - Pre-works check for badger in the immediate vicinity of the proposed works, in areas of proposed vegetation clearance and coppicing in the woodland, should be completed by a suitably qualified ecologist. The pre-works check should also include all access tracks, site compounds

and storage areas where these are required. The pre-works check will identify any recent evidence of badger and setts within 30 m of the proposed works and inform any required mitigation and licensing.

- Reptiles - Vegetation clearance works on the right bank in areas of woodland and scrub should be completed within the reptile active season of April to September, with areas of vegetation cleared methodically to allow reptiles such as grass snake to escape the works area.
- INNS - A pre-works check should be carried out by a suitably qualified ecologist for the potential presence of INNS (terrestrial and aquatic) in or around the works area and access route, where INNS may have become recently established. The findings of the pre-works check will inform mitigation requirements for the works area.
- River Habitat Survey (RHS) – last was completed in 2014. A recent RHS would be useful to establish a consistent baseline of river conditions, including the river corridor and riparian habitats, to inform mitigation requirements and provide baseline conditions against which to measure the success of the Scheme.

4.1.7 Heritage

A study area comprising the Site and a 500m study area from a central point within Erbistock was assessed to understand the archaeological potential of the Site and identify key constraints. A detailed heritage review of the site and initial preferred option (weir removal) was undertaken and is provided in Appendix D.

The study found the following:

- There are two Registered Parks and Gardens and five listed buildings located within the study area. There are no World Heritage Sites, Scheduled Monuments, Conservation Areas or Registered Battlefields within the Site or study area.
- The setting of all of the designated heritage assets identified within the study area does not extend into the Site. The proposed works would not result in physical impacts to, nor change the setting, of any designated heritage asset that would result in any loss of significance.
- There are 23 non-designated heritage assets located within the study area, comprising: 15 non-designated buildings (including Erbistock Mill); 5 earthworks; and 3 structures (including Erbistock weir). Erbistock Mill is no longer in use and was converted into a holiday cottage in the 1970s with the approval of the local planning authority who agreed that the building did not merit a listing (Erbistock Estate *pers. comm.*) and the building has recently been delisted. The proposed works would not result in physical impacts nor change the setting of Eribistock Mill that would result in loss of significance to the Mill. The Mill forms part of the historical functional setting of Erbistock weir, however as the Mill is no longer in use, the historic significance of the weir is reduced. Removal of part of the weir structure would result in the partial loss of a heritage asset which is of local value.
- It is anticipated that construction of the existing structure is likely to have caused disturbance down to, and possibly beyond, bed level, and it is anticipated that any disturbance resulting from the proposed works will be within the confines of the footprint of the existing weir and will not create additional disturbance or change the profile of the existing river bed.
- The assessment concluded a negligible potential for remains dating to all periods expect for the medieval and post-medieval periods, which are deemed to have a low potential for remains. Potential remains dating to the medieval period are likely to relate to evidence of an earlier weir structure. Potential remains dating to the post-medieval period are likely to relate to evidence of restoration or repair works to the weir structure. If identified, it is considered any such remains would be of local value. Extant post-medieval remains, including Erbistock Mill and Weir provide evidence for the management of the waterway and its importance to the economy of the area. For these reasons both have inherent local value.
- The importance and significance of historic landscape character is assessed in terms of sensitivity to change. Those with a high sensitivity to change should be accommodated and preserved where possible within new developments or should be subject to well managed changes. Historic landscapes with a lower sensitivity to change can potentially be enhanced by

new developments and can absorb most types and scales of essential, well-managed change. The Site comprises Erbistock weir which can be characterised as post-medieval industry, which is considered to have low sensitivity to change.

- Further consultation should be undertaken with the Development Control Archaeologist for Wrexham County Council (WCC) during the detailed design phase of the project, in order to discuss the possibility of other less intrusive options for the proposed works on the weir, to reduce the impact on the heritage asset.
- It is not anticipated that archaeological investigation will be required by the Development Control Archaeologist for WCC, however, this would need to be discussed and approved in writing by the Development Control Archaeologist for WCC.

4.1.8 Topographic and Bathymetric Survey

A topographic survey of the site and surrounding area was undertaken. This included a survey at and around the weir, cross sections in the River Dee upstream and downstream extending approximately 600m and 400m from the weir, respectively. The survey was undertaken to refine representation of the system within the hydraulic modelling (see Section 4.2.1).

Surveyed points around the weir itself are indicated in Figure 4-1 below, which shows a reasonable coverage with some gaps in the central weir, which could not be surveyed safely. All surveyed river points are shown in Figure 4-2 below along with an indication of the difference between the measured levels and that in LiDAR data. This shows quite stark differences, particularly upstream of the weir showing the survey depths to be 2m or more deeper than represented in the LiDAR (ultimately showing the benefit of undertaking topographic surveys).

Figure 4-1. Topographic data xyz locations for Erbistock weir (true locations)

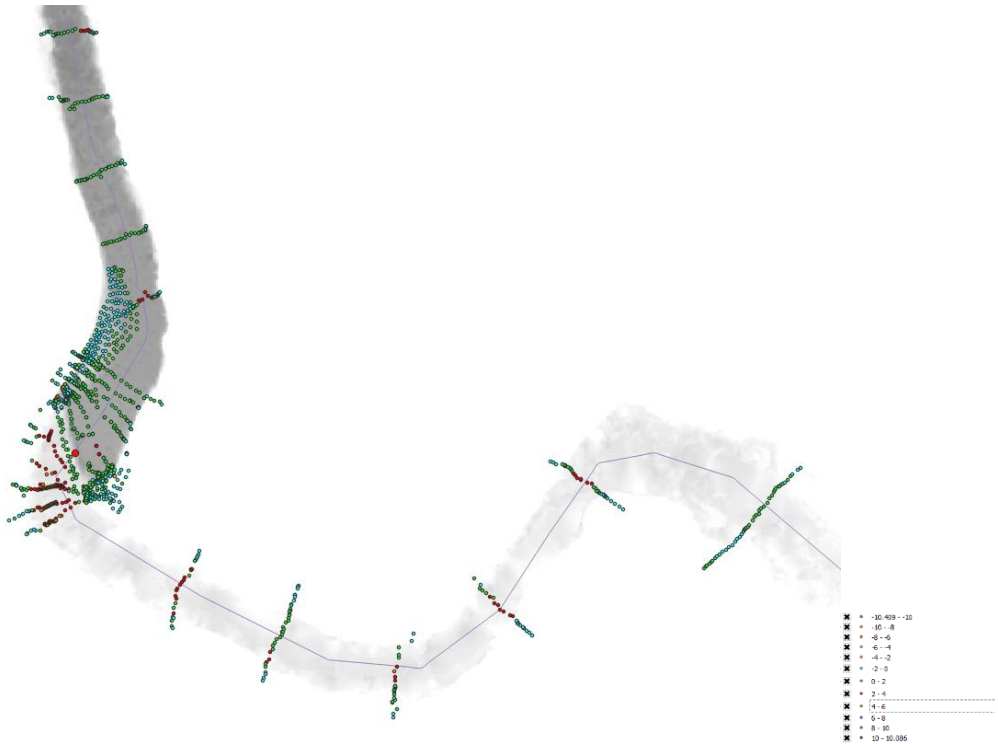


Figure 4-2. Differences between LIDAR and survey xyz data (LiDAR minus survey)

The collected topography layer was integrated into the LiDAR data of the surrounding area to improve representation of the Dee around the weir in the Digital Elevation Model (DEM) that was to be used in the hydraulic modelling. A summary of the final DEM is provided in Figure 4-3 below. This shows levels in the area around 16 to 24m AOD.

Figure 4-3. Topographic survey at and surrounding Erbistock weir

4.2 Design

4.2.1 Hydraulic Design and Fish Passage Review

4.2.1.1 Baseline Modelling

Hydraulic modelling was undertaken to support the design efforts. The overall methodology was outlined in Section 3.3.1 while a more detailed summary of the modelling process at Erbistock is provided in Appendix A.

A baseline model run was constructed (using the DEM indicated above in Figure 4-3), while a number of flow scenarios were run. A Partial Removal run was then constructed and is shown in Figure 4-4 below. A long section plot of around the weir also indicates the reduction in elevation at the weir modelled in the Partial Removal run (Figure 4-5). This indicates a reduction of around 2.5m in levels where the crest of the weir was, with levels graded down downstream. An area of deep water upstream of the weir was indicated, perhaps associated with a pool that is currently drowned by the weir.

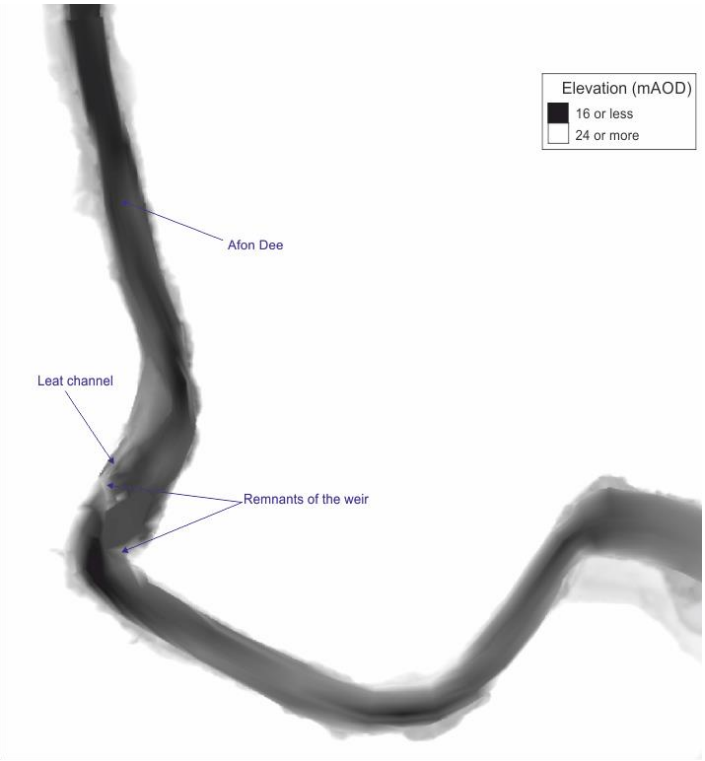


Figure 4-4. DEM for the partial removal of Erbistock weir scenario

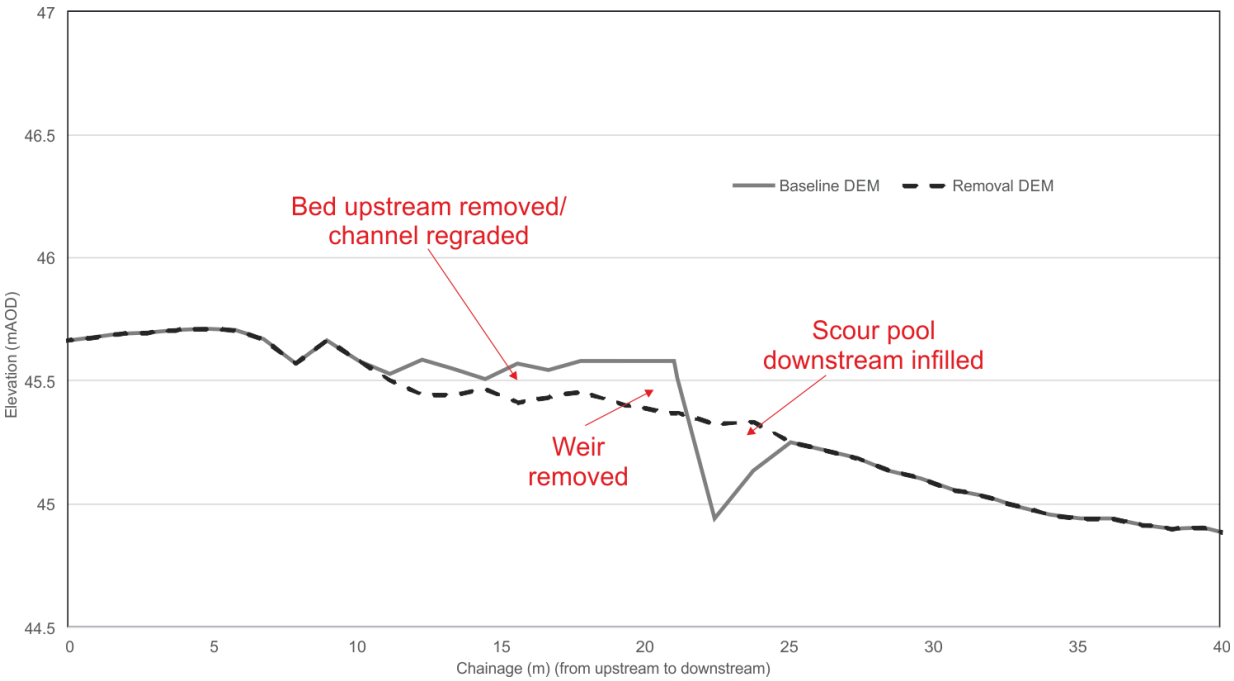


Figure 4-5. Long Profile around the weir under the baseline and partial removal scenarios

4.2.1.2 Design Scenario

A design to improve connectivity at Erbistock weir was developed. The preliminary option under consideration by NRW was partial removal down to bed level of 50% of the width of the weir structure, or to the failed section of the weir, following further discussion with landowner. Optioneering was undertaken to assess the suitability of this option and others for achieving passage for the target species and life stages whilst balancing the requirements of key considerations.

Important considerations for Erbistock weir fish passage improvement design included:

- Improved passage for upstream and downstream migrating salmonids, lamprey and eel across a range of flows
- Access is along approximately 0.7km of agricultural field, which may limit the timing of access. A footpath runs within this access route, adjacent to the river
- Trees adjacent to the site, and upstream within the drawdown reach, may require coppicing
- Road bridge downstream and bridge at Bangor-on-Dee – known blockage risks, impact of trees within drawdown reach falling in and impacting – will need to be considered, including future management
- Structural stability is uncertain
- The selected option must not increase erosion in the vicinity; the bed may need regrading to prevent excess erosion upstream
- A historical footpath exists across the top of the weir, although it appears to no longer be a route that is used
- No increase to public safety risk or flood risk
- Maintenance

The preliminary option was considered the best and recommended option for improving ecological connectivity including for all target species and life stages.

A model comprising partial weir removal was constructed. Plots of velocities and depths for various flows under the baseline and partial removal scenarios are presented in Figure 4-6 and Figure 4-7, respectively. A long profile is also provided in Figure 4-8. Average water depth and velocity at Q_{95} - Q_{10} (Table 4-5) in the area of partial weir removal were sufficient for downstream migrating juvenile,

and upstream migrating adult, salmonids as well as coarse fish species undertaking local migrations[19]. Partial weir removal should also enable passage for eel and lamprey.

[19] Armstrong, G.S., Aprahamian, M.W., Fewings, G.A., Gough, P.J., Reader, N.A. and Varallo, P.V., 2010. *Environment Agency Fish Pass Manual: Guidance notes on the legislation, selection and approval of fish passes in England and Wales*. Environment Agency, Rio House, Bristol http://publications. environment-agency. gov.uk.

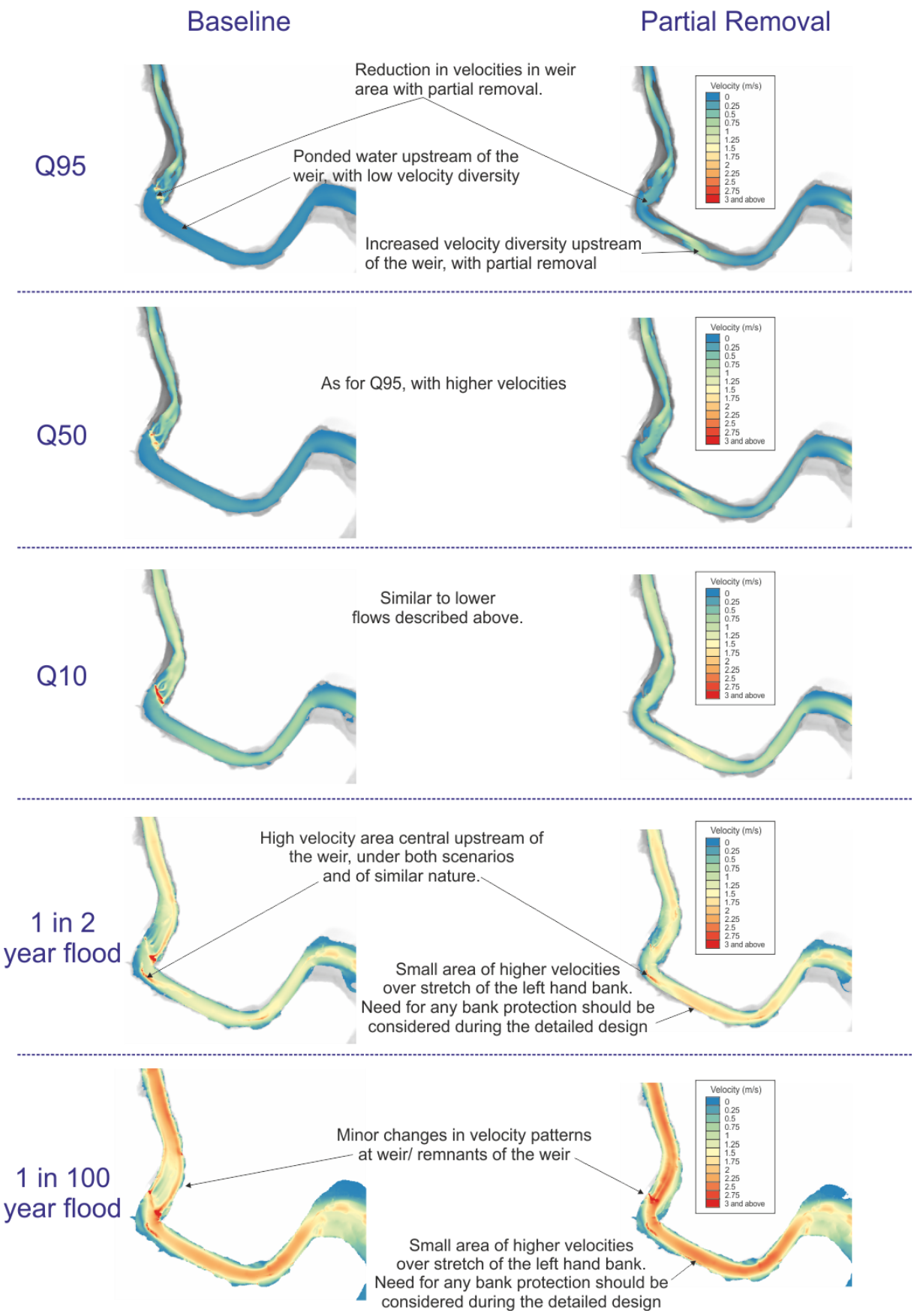


Figure 4-6. Velocity results for various flows under the baseline and partial removal scenarios

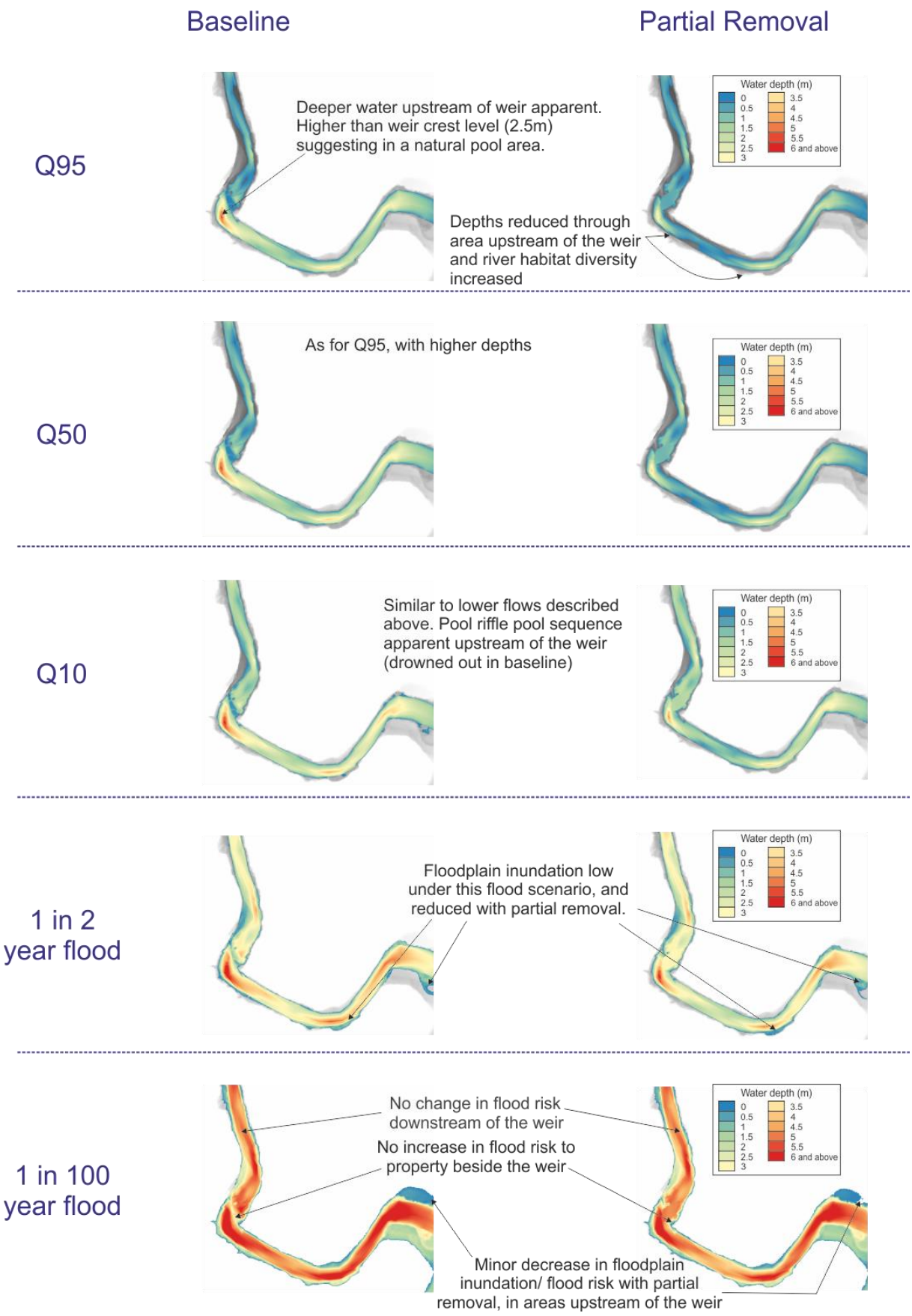


Figure 4-7. Depth results for various flows under the baseline and partial removal scenarios

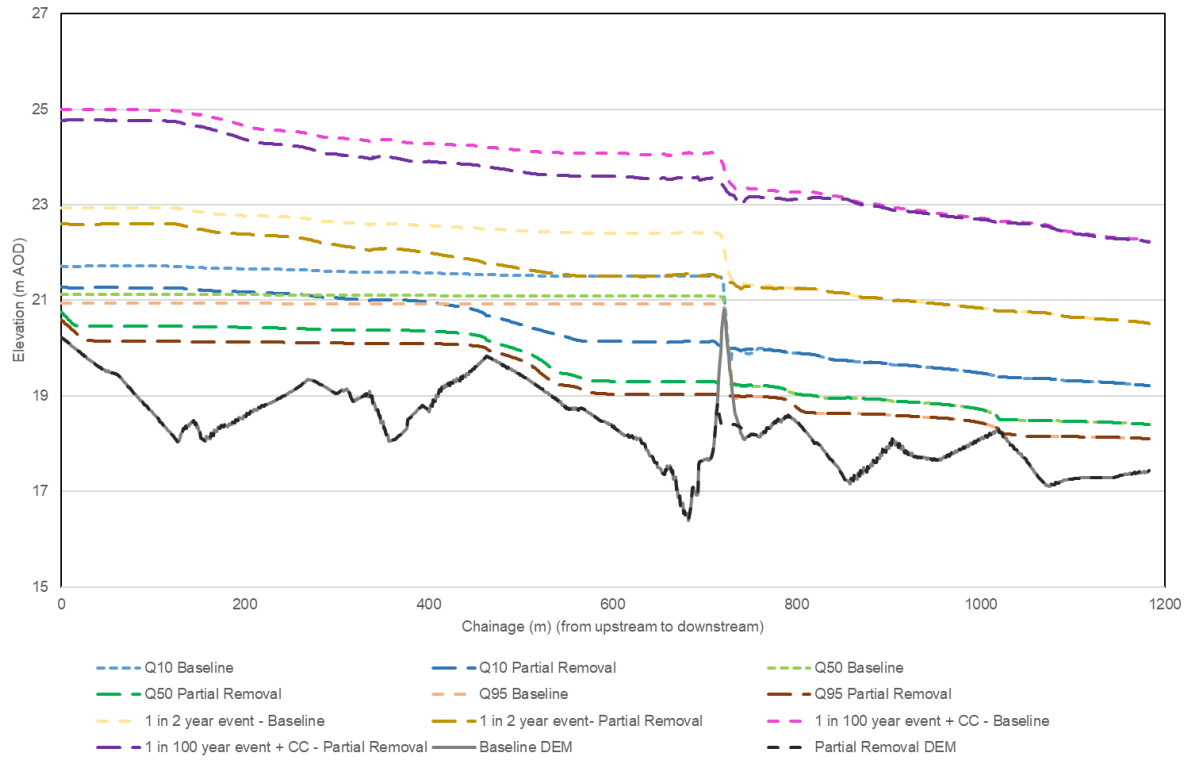


Figure 4-8. Central long profile with water levels for various flows under the baseline and partial removal scenarios

Table 4-5. Approximate maximum baseline and design (partial weir removal) scenario velocities and depths at Q_{95}, Q_{50} and Q_{10} flows

Flow	Velocity (m/s)		Depth (m)	
	Baseline	Design Scenario	Baseline	Design Scenario
Q_{95}	0.50	0.75	0.5	1.0
Q_{50}	1.75	1.00	0.5	1.5
Q_{10}	≥3.00	1.75	1.0	2.0

It seems that the natural pool upstream of the weir prevents there being a significant increase in velocities in the area of the partial removal and would likely delimit any significant re-adjustment of the river in that area, such as knickpoint erosion. The retention of the weir ends should also help the river remain in its current course. It is expected that any re-adjustment would be gradual and the existing pool riffle sequence upstream of the weir, currently drowned out by the weir, would be uncovered. Flood risk in the channel upstream of the weir is slightly reduced as a result of partial removal. There is no increase in flood risk to Erbistock Mill and the associated decked area, with data indicating that a small decrease would be expected.

Results also show a small area of the LHB upstream of the weir may erode. This would provide a benefit to the river, in terms of sediment transfer, but may not be acceptable to the landowners. It is recommended that this is examined further during detailed design, when any need for bank protection should be determined.

Depth of sediment upstream of the weir is not confirmed. Observations indicate it to not be deep, compared to other weir systems, and survey also suggests this to be the case. It is recommended that depths of sediment upstream of the weir are confirmed in support of a detailed design. This would confirm if partial removal would release large volumes of trapped substrate or not.

4.2.2 Design Schematics

4.2.2.1 Access and Utilities

An access and utilities plan was produced and is show in Figure 4-9. Full service results for the site are included as Appendix E. Within the dotted red line boundary an electricity connection to Erbistock Mill is apparent. There is water mains and sewerage mains in the wider area, though these are not indicated within the dotted red line study area. Connections to Eribstock Mill are considered likely, and suggests the utilities information provided is incomplete.

A licensed discharge was indicated in the Groundsure report for the site (already included as Annex I of the contaminated land PRA, Appendix B), on the RHB about 40m upstream of the weir. Mapping of this area indicates a spring / well area. Details of this should be confirmed during detailed design.

4.2.2.2 Plan of the works

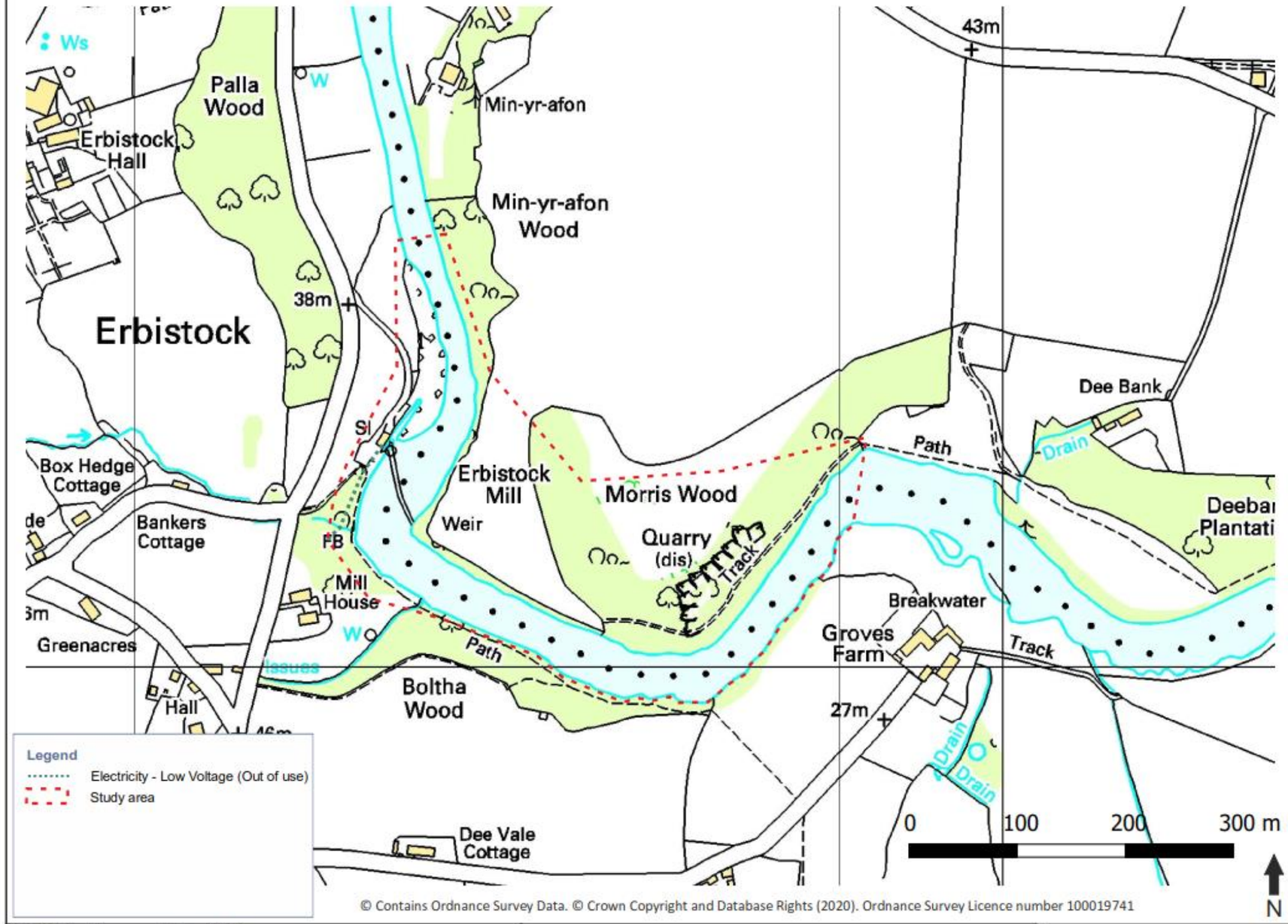
An indicative plan of the works and working area is provided in Figure 4-10.

4.2.2.3 Long Section and Cross Sections

A long section and number of cross sections, indicating baseline and partial removal DEM levels as well as water levels under various flow scenarios are provided in Figure 4-11.

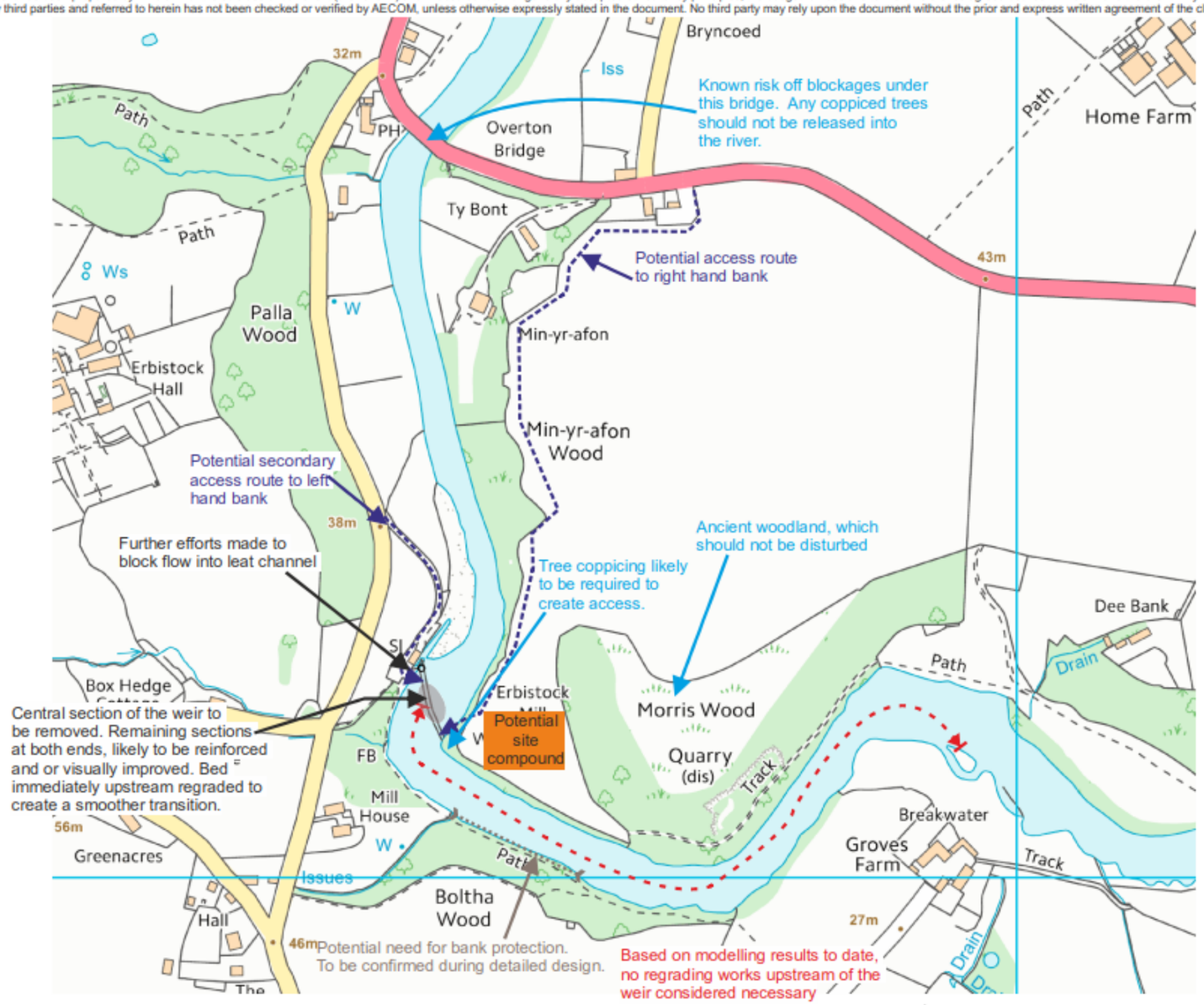
Not for construction

Notes



Client: Natural Resources Wales (NRW)	Cyfoeth Naturiol Cymru Natural Resources Wales / AECOM Bridgewater House 60 Whitworth St, Manchester M1 6LT Tel: +44 (0) 161 907 3500 www.aecom.com	Drawn: PM	Checked: NE
Project: NRW Dee (LIFE) Restoration of Freshwater Features project		Approved: RC	Verified: OS
Title: Erbistock utilities		Drawing Number: Erb.1	Version Number: 1

Figure 4-9. Utilities Plan in study area around Erbistock weir



Not for construction

Notes

Preliminary Bat Roost Assessment and pre-construction checks for nesting birds, otter, water vole, badger, reptiles and INNS required if coppicing and vegetation clearance required. Clearance should be completed April - September.

Non-native invasive species (such as Japanese Knotweed) are present – should be suitably accounted for during any works.

Areas to be kept dry during works, e.g. through placement of sandbags or similar, at top and bottom and where required at sides. Right hand side works potentially undertaken first with works on both sides undertaken at different times with other half of channel remaining unconstrained.

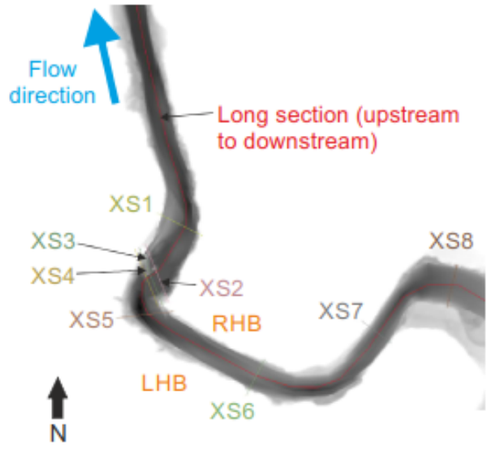
Client: Natural Resources Wales (NRW)	Cyfoeth Naturiol Cymru / Natural Resources Wales; AECOM	Drawn: PM	Checked: OS
Project: NRW Dee (LIFE) Restoration of Freshwater Features project	1 New York Street, Manchester Tel: +44 (0) 161 601 1700 www.aecom.com	Approved: GW	Verified: NW
Title: Erbistock indicative plan of works		Drawing Number: Erb.2	Version Number: 1

Figure 4-10. Indicative Plan of works around Erbistock weir

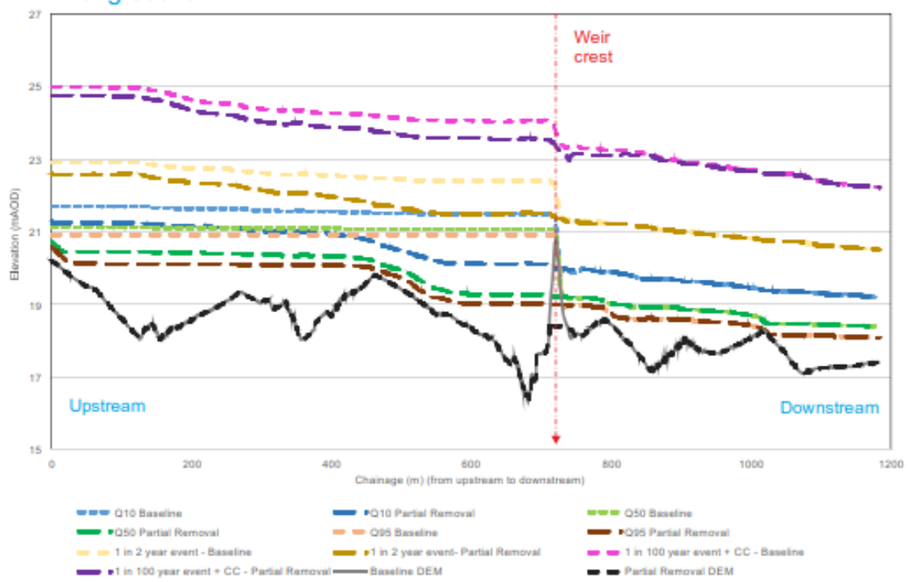
Not for construction

Notes

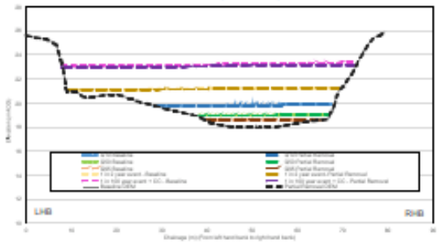
Location of sections



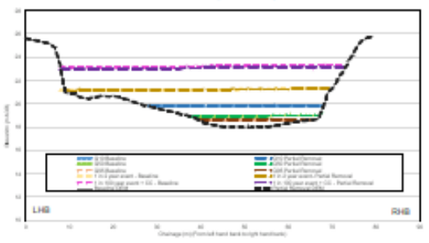
Long section



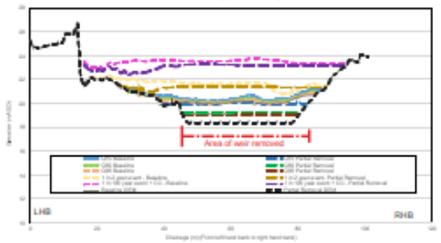
Cross section 1 (XS1)



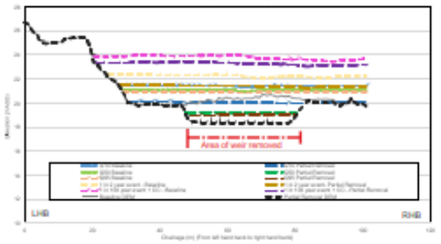
Cross section 2 (XS2)



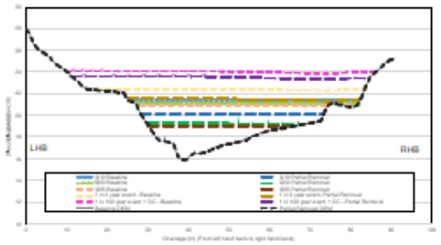
Cross section 3 (XS3)



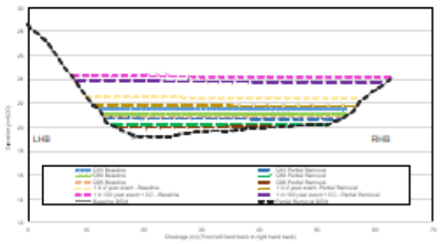
Cross section 4 (XS4)



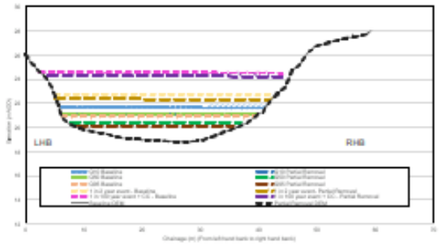
Cross section 5 (XS5)



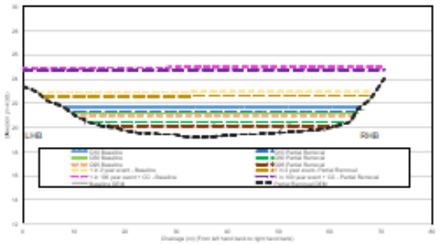
Cross section 6 (XS6)



Cross section 7 (XS7)



Cross section 8 (XS8)



Client: Natural Resources Wales (NRW)	Cyfoeth Naturiol Cymru Natural Resources Wales / AECOM 1 New York Street, Manchester Tel: +44 (0) 161 601 1700 www.aecom.com	Drawn: PM	Checked: OS
Project: NRW Dee (LIFE) Restoration of Freshwater Features project		Approved: GW	Verified: NW
Title: Erbistock long section and cross sections		Drawing Number: Erb.3	Version Number: 1

Figure 4-11. Long section and channel sections showing Baseline and Partial Removal scenario DEM levels and water levels for various scenarios

5. Next Steps and Recommendations

Partial removal of Erbistock weir has been identified as the preferred option for improving fluvial and ecological connectivity. Sections 5.1.1 and 5.1.2 summarise key next steps and recommendations.

5.1.1 Detailed Design

Services

- An electricity connection to Erbistock Mill exists and should be taken into consideration when planning weir removal works and access. Although not depicted in the Groundsure report, other connections to Eribstock Mill are considered likely, and suggests the utilities information provided is incomplete and requires further investigation. A licensed discharge was also indicated in the Groundsure report on the right bank about 40m upstream of the weir. Mapping of this area indicates a spring / well area. Details of this should be confirmed during detailed design.

Ground Condition and Contaminated Land

- Ground setting and therefore conditions for works access are unknown. It is recommended that a geotechnical assessment is carried out prior to any works to assess the suitability of access for plant and the stability of the weir.
- State of surface water quality is unknown and therefore the impacts of sediment release on the downstream environment cannot be assessed. Surface water samples should be taken to enable a baseline to be established and assess the presence and concentrations of CoPCs. Upon completion of the works and bed regrading, samples should be taken from the new interface between the sediment and the overlying water column to verify that levels of contamination are within the range detected during the baseline assessment.
- Depending on the results of the ground investigation (Section 4.3.1), mitigation measures may be required to manage any risks, which could include excavating and removing sediments, with waste classification and appropriate treatment / disposal, or capping sediments during the works.
- Geophysical surveys such as ground penetrating radar will be needed to properly understand the depth of substrate to solid bedrock.
- Sediment sampling and analysis should be carried out from locations within the vicinity of the proposed works to assess particle size distribution. Assuming fine material is present, samples should be chemically tested to determine the presence and concentrations of CoPCs associated with historic land uses. Sediment samples should also be classified for waste disposal designation and the potential costs associated with the this. There is the potential to explore the deposition of sediments in the vicinity of the weir subject to regulatory agreement.

Ecology

- Impacts to semi-natural broadleaved woodland (a habitat of high ecological value) should be minimised reinstated to a similar condition upon completion of the works. The woodland on the right bank is connected to an area of Ancient Woodland (Morris Wood / Neile's Wood) approximately 120 m east of the weir and impacts to ancient woodland should be avoided.
- Preliminary Roost Assessments are required to assess the potential for the trees to support roosting bats and the impacts of any proposed coppicing/ access routes. The surveys will also identify any further surveys required for roosting bats and subsequent licensing.
- The woodland on the right bank, and the right bank itself in terms of kingfisher and dipper, are of high value habitat for nesting birds. The proposals include the removal and / or coppicing of trees on the right bank, and therefore further investigation will be required for nesting birds, should vegetation clearance be carried out in the main bird nesting season of March to September.
- A RHS was last was completed in 2014. A recent RHS would be useful to establish a consistent baseline of river conditions, including the river corridor and riparian habitats, to inform mitigation requirements and provide baseline conditions against which to measure the success of the Scheme.

- The Scheme is located within the River Dee and Bala Lake SAC, which is designated for aquatic habitats and species, and is also designated as a SSSI. It is not considered that there will be any adverse impacts on the SAC/SSSI; however, the relevant statutory bodies should be consulted to undertake Habitats Regulations Assessment screening, to determine whether the Scheme requires Appropriate Assessment.

Hydraulic Design and Hydromorphology

- Modelling results identified that a small area of the LHB upstream of the weir may erode. This would provide a benefit to the river, in terms of sediment transfer, but may not be acceptable to the landowners. It is recommended that this is examined further during detailed design, when any need for bank protection should be determined.
- Depth of sediment upstream of the weir is not confirmed. Observations indicate it to not be deep, compared to other weir systems, and the survey also suggests this to be the case. It is recommended that depths of sediment upstream of the weir are confirmed in support of a detailed design. This would confirm if partial removal would release large volumes of trapped substrate or not.
- Structural integrity of sections intended to remain is unknown. This should be confirmed to inform the detailed design.

Fish Pass Design

- Final detailed design is subject to stakeholder engagement and agreement, which should be embarked upon at the earliest opportunity and continue throughout the design process.
- Structural integrity of the weir is unknown and should be investigated.

5.1.2 Other

Ecology

- Pre-works checks relating to tree coppicing/removal and vegetation clearance would also be required for nesting birds, otter, water vole, badger and reptiles to inform mitigation and licensing requirements. Vegetation clearance is recommended between April and September.
- INNS (Japanese knotweed and Himalayan balsam) were noted during the site visit. A pre-works check should be carried out by a suitably qualified ecologist for the potential presence of INNS (terrestrial and aquatic) in or around the works area and access route, where INNS may have become recently established. The findings of the pre-works check will inform mitigation requirements for the works area.

Heritage

- Further consultation should be undertaken with the Development Control Archaeologist for Wrexham County Council (WCC) during the detailed design phase of the project, in order to discuss the possibility of other less intrusive options for the proposed works on the weir, to reduce the impact on the heritage asset.
- It is not anticipated that archaeological investigation will be required by the Development Control Archaeologist for WCC, however, this would need to be discussed and approved in writing by the Development Control Archaeologist for WCC.

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