LIFEDeeRiver

Restoration of Freshwater Features

LIFE18 NAT/UK/000743

Natural Resources Wales

Horseshoe Falls Weir

Final Report

Project Number: 60627686

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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 Horseshoe Falls 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.

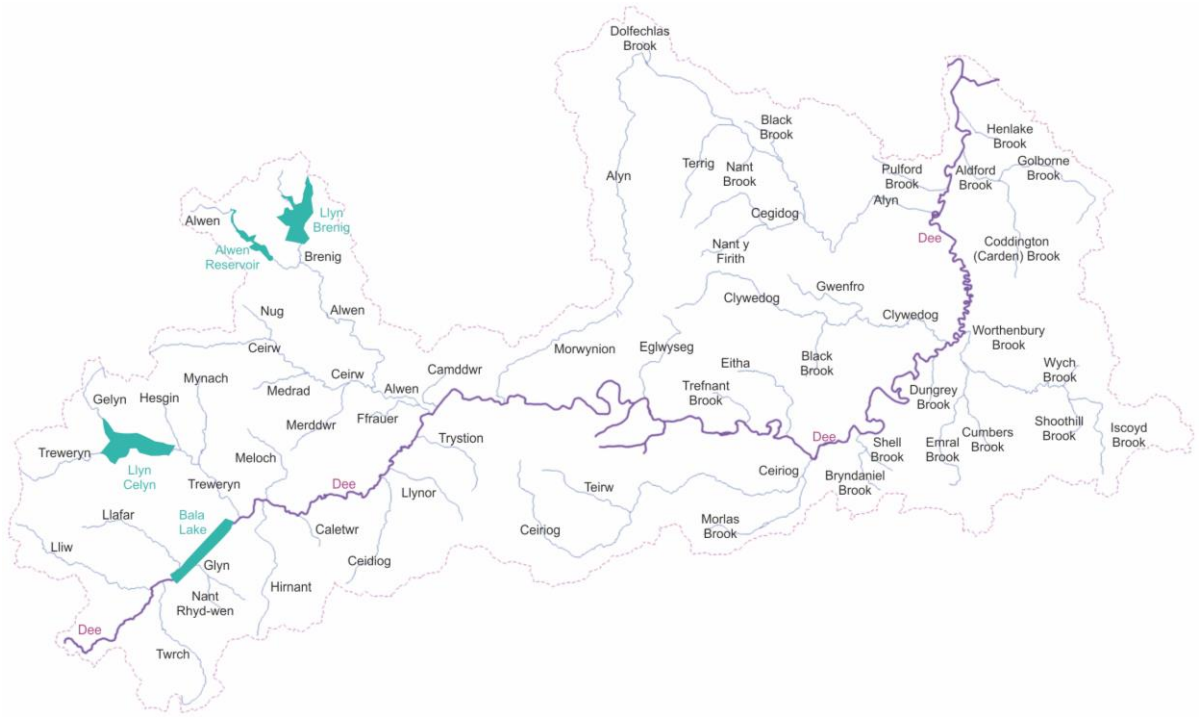


Figure 2-1. Catchment map for the River Dee

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 (Section 4);
- Llangollen Upstream weir;
- Llangollen Downstream weir;
- Morlas Ford weir;
- Erbistock weir; 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'*

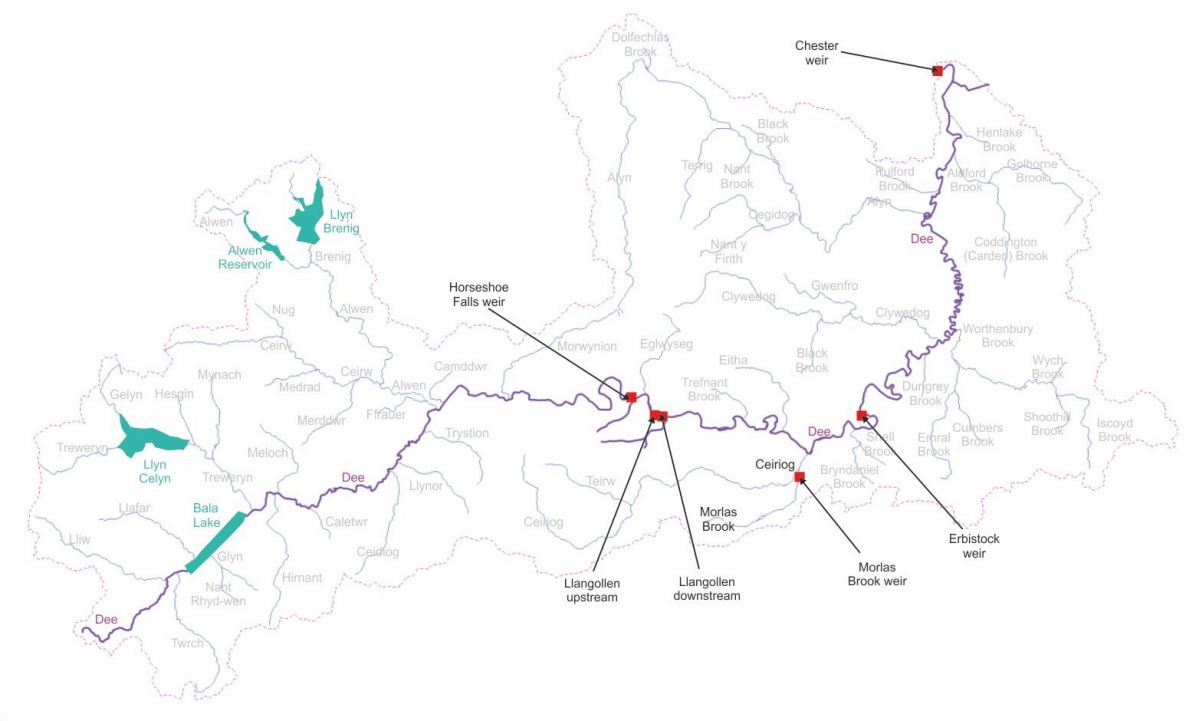


Figure 2-2. Six weirs located in the Dee catchment selected for fish passage improvements

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

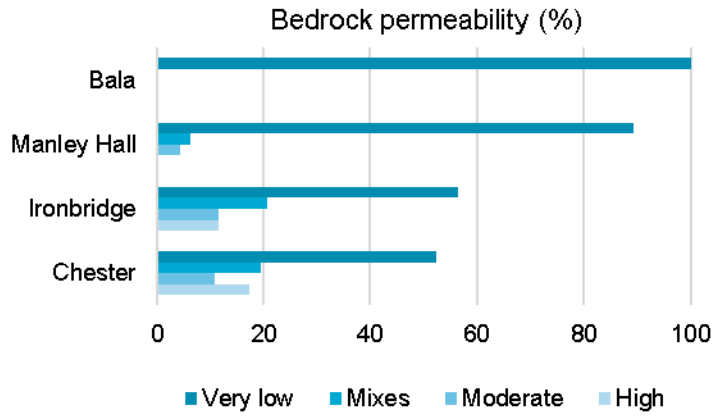
2.2 Catchment Geology/ Hydrogeology

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

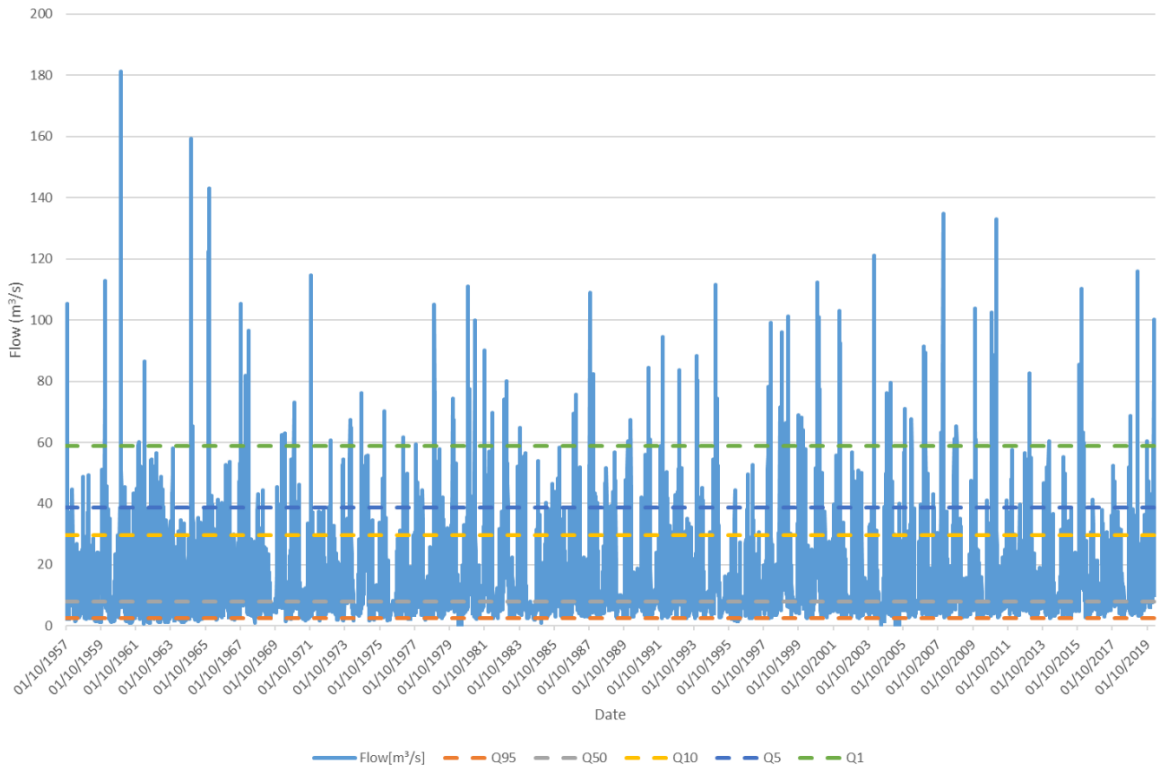


Figure 2-4. Hydrology information at Bala gauge station[7]

[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

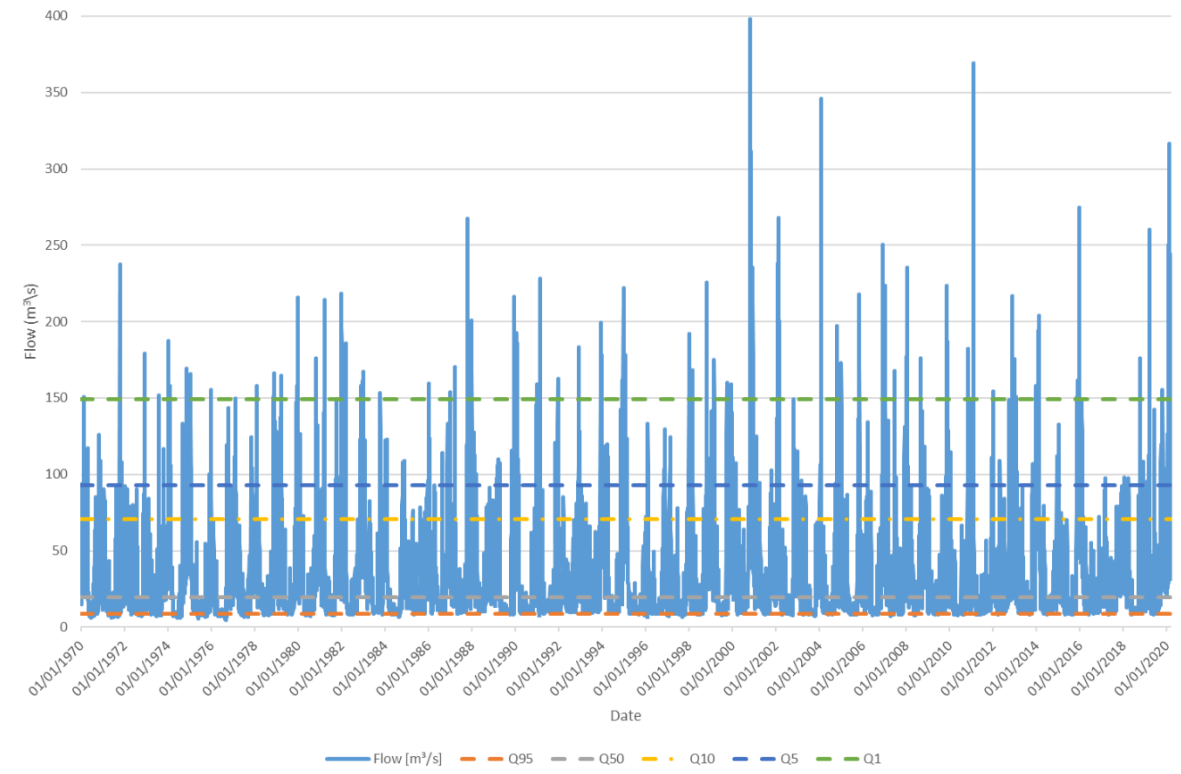


Figure 2-5. Hydrology information at Manley Hall gauge station[8]

[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

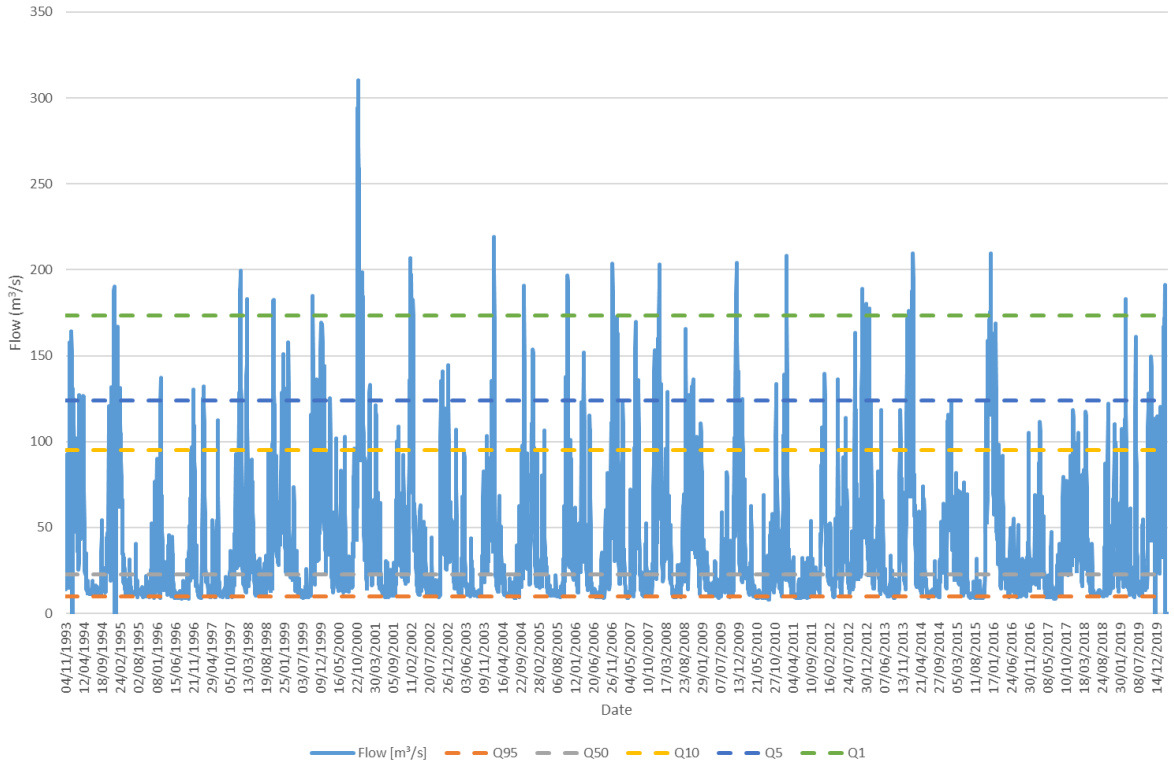


Figure 2-6. Hydrology information at Ironbridge gauge station[9]

[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

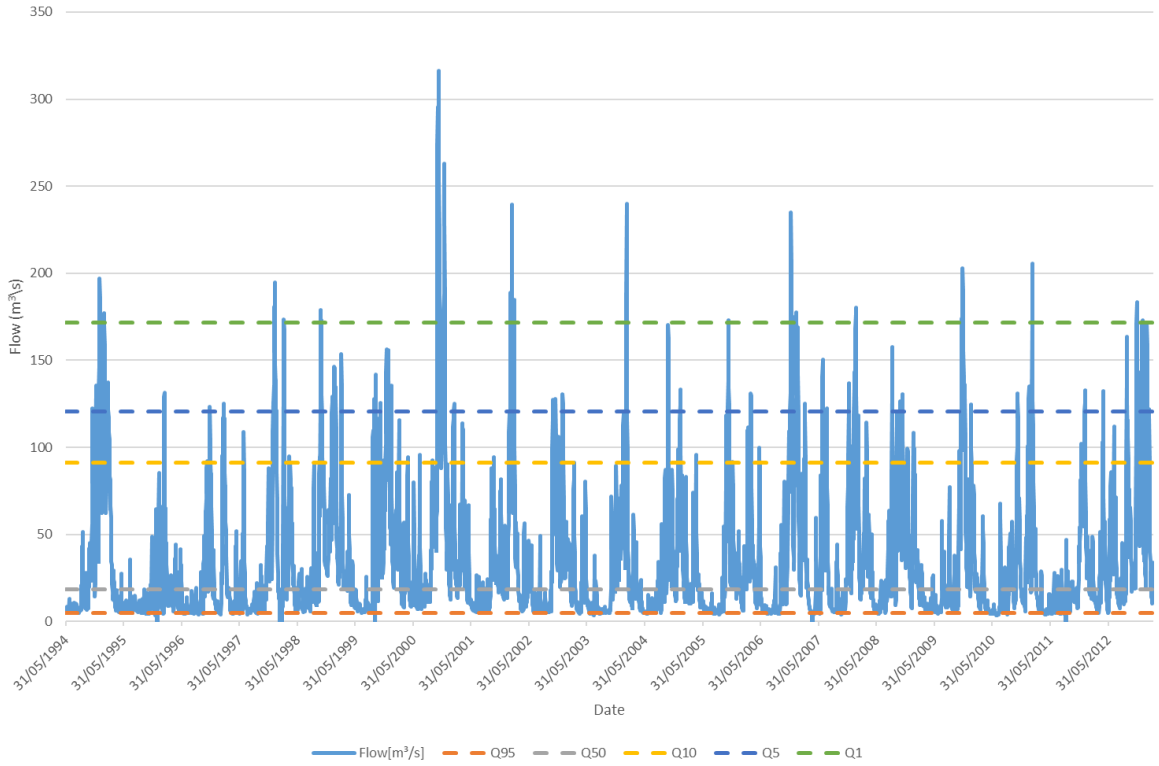


Figure 2-7. Hydrology information at Chester Suspension Bridge gauge station[10]

[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. Horseshoe Falls Weir

4.1 Baseline Conditions

4.1.1 Site

The site is situated on the River Dee in Denbighshire, north east Wales, approximately 2.3km north west of Llangollen town centre. The site comprises a weir spanning the majority of the width of the River Dee, falling short from the eastern bank to allow for the navigation of the Shropshire Union Canal Llangollen Branch. The site lies approximately 85m above ordnance datum (AOD).

The weir is a large horseshoe shaped structure that has an existing abstraction associated with it for the Llangollen canal. The offtake of the canal is on the LHB and has existing screening in place to prevent fish entrainment. The weir is part of a World Heritage Site. It extends for approximately 145m, has a vertical downstream face with a head difference of approximately 1.5-2m.

At project onset the preferred fish passage option was a nature like bypass channel on the RHB.

The site is found in a river setting environment and flows from west to east, where the river then meanders and flows from north to south. To the west of the weir, adjacent to the River Dee, is an area of land, where a fish bypass channel could be constructed. The area of land is presumably used for agricultural purposes, specifically for pasture grazing. To the north of the site, land use is predominately areas of open field, presumably used for arable agriculture. A hotel and church are also found to the north. Downstream of the weir and to the east, an area of public open green space lies directly adjacent to the site. The B5103 is beyond this that eventually leads to a bridge that crosses the River Dee downstream from the site. An outdoor education centre is also present. To the south, the site is bounded by the A5 road that cuts through an extensive patch of woodland. Directly adjacent to the site is the Llangollen Railway, which spans the entirety of the southern site boundary at notably higher elevations than the river with a steep topography between the two.

The Canal and Rivers Trust (CRT) commissioned a review of the condition of the weir[19]. The findings were that the weir itself is in a fair condition, with minor uneven flow over the crest of the weir as a result of small voids under the breadth of the crest. Recommendations to improve the overall condition included repairing weir crest masonry, removing debris and vegetation caught on or adjacent to the crest and removing potentially unsafe platform attached to west of the training wall (the latter appears to have been actioned). While seemingly homogeneous from a distance, the review indicated that the weir is comprised of a number of components including metals plates, bars, flanges etc indicating that it has been modified and repaired since originally constructed (completed by 1808).

4.1.2 Site Visit

The site was visited on 16 July 2020. Images from this, complimented by imagery from the survey (see Section 4.1.8), are presented in Plates 4-1 through to 4-33. The hydromorphology of the site is discussed further in Section 4.1.4 and was informed by the site visit.

The historic value of the site was evident, particularly with a number of visitor information boards located in the vicinity of the weir. Heritage is discussed further in Section 4.1.7.

CRT have an abstraction for Shropshire Canal just upstream of the weir (LHB). Existing screens are located between the main river channel and the canal feeder stream. At the start of the canal feeder stream there is a sluice that enables some flow to return to the river while flow that continues down the feeder stream must flow through a culvert under an ops building (which contains a flow monitor measuring flow into the canal). Maximum annual abstraction at the site amounts to 18,300 Ml/yr while the daily maximum abstraction amounts to 82.96 Ml/d (0.96 m^3/s).

[19] Principal Inspection Report, LA-075-006 Horseshoe Falls Weir (ARCADIS 2018). Report Ref: UA007159-ARC-XX-XX-RP-CE-0006.

The abstraction for this is managed by CRT. The existing screens are not compliant with the Eels (England and Wales) Regulations 2009, for which an exemption has been granted by the EA. United Utilities are currently investigating the provision of new screens to prevent eel entrainment at the abstraction from the River Dee into the canal feeder stream. It is understood that the current preferred screening option also entails notching the weir just downstream of these screens to help prevent trash building up at the screens.

On the opposite bank, Hafren Dyfrdwy own a building, believed to be a pump house, and a small plot of land through which a bypass could otherwise flow through.

Plate 4-1. Horseshoe Falls weir (looking from LHB)- panoramic view

Plate 4-2. Horseshoe Falls weir (looking from LHB)

Plate 4-3. Horseshoe Falls weir (looking from LHB across weir)

Plate 4-4. River Dee upstream of Horseshoe Falls weir (looking downstream)

Plate 4-5. River Dee upstream of Horseshoe Falls weir (looking upstream)

Plate 4-6. River Dee upstream of Horseshoe Falls weir (looking across the channel from LHB)

Plate 4-7. Snapshot from Horseshoe Falls weir information board

Plate 4-8. Snapshot from Horseshoe Falls weir information board

Plate 4-9. Snapshot from Horseshoe Falls weir information board

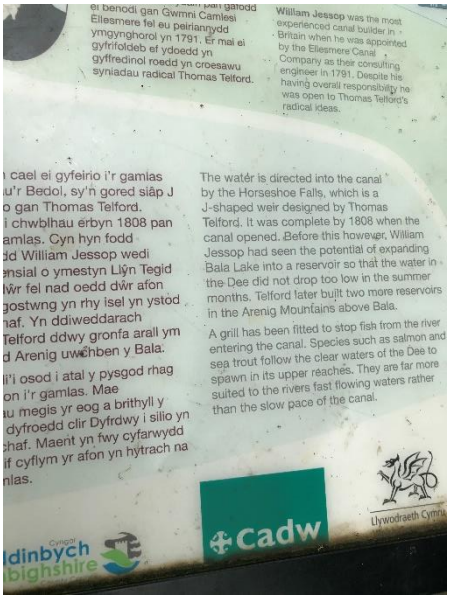


Plate 4-10. Snapshot from Horseshoe Falls weir information board

Plate 4-11. Structure in channel at weir (one end of where stoplogs can be inserted to dry up channel to canal for when that is maintained)

Plate 4-12. Screens at entrance to canal feeder stream

Plate 4-13. LHB end of the weir/ screens at entrance to CRT on the left

Plate 4-14. Screens from canal feeder stream side

Plate 4-15. Screens and surrounding structures

Plate 4-16. Looking along the weir crest from LHB

Plate 4-17. Building above the canal feeder stream, under which channel is culverted and flow is monitored

Plate 4-18. Start of canal feeder stream

Plate 4-19. Horseshoe Falls weir from RHB- panoramic view

Plate 4-20. Horseshoe Falls weir from RHB (central section including rock outcrop)

Plate 4-21. Horseshoe Falls weir from RHB

Plate 4-22. Downstream of Horseshoe Falls weir (RHB) looking upstream

Plate 4-23. RHB end of Horseshoe Falls weir

Plate 4-24. Downstream of Horseshoe Falls weir (RHB) looking across the channel- panoramic view

Plate 4-25. Downstream of Horseshoe Falls weir (RHB) looking downstream

Plate 4-26. Deposited materials downstream of Horseshoe Falls weir (RHB)

Plate 4-27. Field through which bypass channel may flow (looking towards the north)

Plate 4-28. Field through which bypass channel may flow (looking towards the west/ general upstream direction)

Plate 4-29. Field through which bypass channel may flow (looking towards the west/ general upstream direction)

Plate 4-30. Hafren Dyfrdwy land and pump house

Plate 4-31. Angling sign LHB

Plate 4-32. Angling sign RHB

Plate 4-33. River Dee from downstream of the weir from the B5103 bridge

4.1.3 Water Framework Directive

The weir lies in the Dee Ceiriog to Alwen WFD surface waterbody (GB111067052060). The waterbodies have a 2016 classification of Moderate, with chemical as failing and ecological rating as Good. The study area is within the Dee Silurian/ Ordovician Ground waterbody (GB41102G200200) which has an overall 2016 status of Good whilst chemical status is Good and quantitative status is Good.

4.1.4 Hydromorphology

The River Dee in the vicinity of Horseshoe Falls weir is a single thread, meandering channel flowing through a moderately confined U-shaped valley. The watercourse flows through superficial deposits of alluvium and Devensian till, overlying bedrock of mudstone, siltstone and sandstone (Elwy formation). There are natural bedrock outcrops at the weir (hence the strategic weir location), with the structure used to heighten the natural bed rock profile and extend a crest level across the full channel width. Bank protection is also evident upstream as channel training to reinforce the channel form toward the weir and contain attenuated flow levels.

Upstream of the weir there is a floodplain present on both banks, and the wide band of alluvium suggests that the watercourse would historically have been relatively mobile. Topography suggests a series of terraces across the valley floor southwest of Llantysilio Hall, implying sequential downcutting into glaciofluvial deposits concurrent to the meander apex migrating south west. This suggests a slow rate of channel evolution, with the bedrock outcrop being a rigid control on channel form prior to weir construction.

The watercourse is impounded for approximately 800m upstream of the weir and the flow regime through this reach is dominated by slow moving gliding flow with no variation. The weir acts as a barrier to sediment continuity and as a result the reach upstream is considered to be a sediment sink,

although natural bedrock at the weir would have a similar effect to a lesser extent. Some erosion of the left bank as a result of hydraulic scour has been noted upstream of the weir, as well as geotechnical failure and bank erosion as a result of poaching on the right bank.

Sparse coarse gravel is visible in the channel downstream of the weir, and a large (3.11 – 6.8% of reach area) in-channel bar is reported[20] but it is not entirely clear what this refers to. AECOM's site visits identified bedrock typology at the weir continuing through the narrow valley extending eastwards to the confluence with the Afon Eglwyseg approximately 1km downstream. The natural bedrock channel would not be expected to have significant, habitat forming gravel deposits.

Overall, the bedrock dominated channels mean that geomorphological risks are low for the preferred options of a bypass channel around the structure, and similarly for structure modifications for technical fish passage. Morphologically, structure removal is always preferable for river continuity, but other factors such as World Heritage Site status and water supply to the Shropshire Union Canal are likely to be overriding factors in this case.

4.1.5 Contaminated Land PRA

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

[20] Hill, C. and Emery, J. (2004), *'Fluvial Audit of the River Dee'*

Table 4-1. Horseshoe Falls PRA findings

Conclusion	Design Implications	Recommendations
The desk study identified that: • Published Geology of the site and the Groundsure reports demonstrate that Alluvium, a Secondary A Aquifer, underlies the majority of the site, with a small portion to the north east underlain by Devensian Till, a Secondary Undifferentiated Aquifer. Bedrock deposits are formed of the Elwy Formation and are classed as a Secondary B Aquifer. • On site ground setting is not confirmed 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 and current land use on and surrounding the site could contribute to environmental impacts.	Route of access to the site, for the construction of the bypass channel, and ground conditions on site are unknown. The implications to the design caused by this may be unsuitable ground for access and construction. Surface water composition is unknown. No implication to the design is thought to be caused by this, however a baseline of current water conditions should be obtained to determine any impacts as a result of the construction of a fish bypass channel, or alternate fish pass involving significant earth works. Impacts of the proposed fish bypass channel to controlled waters is unknown. Excavation of materials is anticipated to occur as a result of the construction of the bypass channel. The implication to the design could be changes in how excavated materials are stored on site. It is not known what wastes will be produced from the proposed works how these wastes are to be dealt with. The situation of the site lying in a World Heritage Site, an area of outstanding natural beauty and Grade II listings of on site buildings and on site registered parks and gardens may change the location or methods to how the bypass channel is constructed.	If a bypass channel is progressed, a series of window samples holes should be carried out in the main on site field. The window samples should be progressed in order to determine physical, from a geotechnical perspective, and chemical properties of the superficial deposits and to determine the depth of rock head which may impede the construction of the bypass channel. The window samples should be carried out to refusal or to where a defined water table is found. The obtained groundwater level can be used to determine how site groundwater deposits feed into the River Dee. Window samples should also be carried out as close to, or if it is permitted, on the land where the pump house is located to determine if made ground is present should the proposed bypass channel be designed in close proximity of the pump house. In addition to these locations, some window samples should be progressed as close to the south boundary of the on site field as possible. These locations will aid insight into whether any potential off site contamination, associated with the railway, is migrating on site. Environment samples will be taken of the soils and shallow strata to give insight into the presence and concentrations of Chemicals of Potential Concern (CoPCs) associated with the land use. Geotechnical samples should also be collected to determine the suitability of the ground for the proposed bypass channel. Other onsite geotechnical tests should be carried out to determine suitability for the access road. Surface water samples should be taken from the River Dee. 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 fish bypass channel, surface water should be sampled again, in the same locations, to highlight any changes in chemical composition of the water. Upon completion of the fish bypass channel, surface water samples should also be taken of the channel. This should be done on only if the bypass channel is excavated through Made Ground (potentially near the pump house) or if it is expected that there are non-natural inputs to the channel. If determined necessary, sampling should be carried out on at least three occasions post completion, reduced if no concerns are raised from the lab analysis. This will not necessarily aid any insight for the reassessment of current pollutant linkages, however, will be useful to monitor the water quality of the new channel. Considerations should be taken as to what waste is produced, how it is stored and methods of disposal. Dependant on the outcome, classification of wastes may be required if offsite disposal is to be considered. Appropriate heritage assessments should be carried out before any intrusive works are conducted, if not already conducted (see Section 4.1.7). There should be a further detailed assessment of the mining risks in the area as a result of the localised small-scale underground mining of a vein mineral that occurred in the area. This assessment should be carried out prior to any intrusive works carried out.

4.1.6 Ecology

4.1.6.1 Overview

A PEA was undertaken at Horseshoe Falls weir (Appendix C). Key details from the PEA are outlined below.

4.1.6.2 Designated Sites

International Statutory Designated Sites

There are three international statutory designated sites within 10km of Horseshoe Falls 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 Horseshoe Falls weir

Site Name	Designation	Description	Distance and Bearing from weir
River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid	SAC (Wales) and SAC (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.*	0 m
Berwyn a Mynyddoedd De Clwyd / Berwyn and South Clwyd Mountains	SAC (Wales)	Berwyn and the South Clwyd Mountains are designated for the Annex I habitats which they support, including the largest stands of European dry heath in Wales and an extensive tract of near-natural blanket bog.	1,410 m SW; 2,510 m NE and; 1,540 m N
Berwyn	Special Protection Area (Wales)	Berwyn SPA is an extensive area of heather moorland running south west from Llangollen in the north east to Mallwyd. It is designated primarily as it supports internationally significant populations of hen harrier *Circus cyaneus*, merlin *Falco columbarius,* peregrine *Falco peregrinus* and red kite *Milvus milvus* as well as other notable and protected upland breeding bird species.	9,920 m NW

National Statutory Designated Sites

There are three national statutory designated sites within 2km of horseshoe Falls weir, summarised in Table 4-3.

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

Site Name	Designation	Description	Distance
Afon Dyfrdwy (River Dee)	SSSI (Wales) and SSSI (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.*	0 m
Berwyn	SSSI (Wales)	Berwyn SSSI is the largest heather moorland area in Wales, designated for its upland blanket bog habitats, which support upland breeding birds and birds of prey as well as many notable and protected plant species. Red squirrels have re-established themselves in some woodland areas particularly where the indigenous spruce has regenerated.	820 m SW
Ruabon/Llantysilio Mountains and Minera	SSSI (Wales)	The calcareous screes and grasslands of the Ruabon and Llantysilio Mountains and Minera are designated as they support many rare species such as the limestone fern *Gymnocarpium robertianum* and rigid buckler fern *Dryopteris submontana* which is nationally scarce. The site also holds populations of the endemic whitebeam *Sorbus anglica* and Welsh Hawkweed *Heiracium cambricum,* while the calcareous grasslands contain several types of neutral, upland acid and calcareous grassland, along with areas of bracken and scrub. This area holds the only Welsh locality for the critically endangered Sedge *Carex muricata* ssp. *muricata*.	1,450 m N

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

Non-statutory Designated Sites

There are 11 non-statutory site designations within 2km of the site, 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 2km of Horseshoe Falls weir

Site Name	Designation	Distance from site (m)
North West_SWSGZ3011_Hurleston	Drinking Water Safeguard Zone (Surface Water) (England)	110 m
Velvet Hill	Local Wildlife Site	240 m
Llangollen Canal	Local Wildlife Site	620 m
Velvet Hill	Regionally Important Geodiversity Sites	910 m
River Dee	Local Wildlife Site	1,190 m
Ddol Fawr (within geological SSSI)	Local Wildlife Site	1,220 m
Llanarmon yn Ial Cave	Regionally Important Geodiversity Sites	1,420 m
Pheasant	Local Wildlife Site	1,450 m
The Birches, Fron Fawr	Local Wildlife Site	1,470 m
Tan-y-bwlch	Local Wildlife Site	1,590 m
Cae Madog Wood	Local Wildlife Site	1,730 m

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 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.
- 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 and on the vegetated islands downstream of the weir is identified as woodland Priority Habitat, and any losses of this habitat should be replaced on a like-for-like basis.
- Areas of semi-improved grassland and tall ruderal vegetation are also of high ecological value for a range of species, and similar areas of these habitats to those lost should be built into the design of the Scheme. Areas of poor semi-improved grassland to be lost through the creation of the bypass channel should be compensated for by the creation of habitats of higher ecological value such as semi-improved grassland and broadleaved woodland.
- Habitats created through the Scheme, including the bypass channel and associated habitats, should be subject to an on-going management plan to ensure that they establish satisfactorily to replace habitats lost. The management plan should cover a period of five years from completion of the Scheme, unless otherwise specified by the Local Planning Authority.

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:

- Birds (full list of species in Appendix C);
- Flowering plants (bluebell, floating water-plantain, meadow saxifrage);
- Insects (small heath, grayling, wall, brown hairstreak);
- Molluscs (freshwater pearl mussel);
- Mosses (flat-rock grimmia, bordered screw-moss);
- Reptiles (slow worm, grass snake, adder);
- Water vole;
- Hedgehog;
- Otter;
- Badger;
- Bats (Daubenton's bat, whiskered/ Brandt's bat, common pipistrelle, soprano pipistrelle, brown long-eared bat);
- Fish (Atlantic salmon, brown trout, European eel, lamprey sp., bullhead); and
- INNS (Himalayan balsam, montbretia, butterfly bush and potentially cotoneaster, non-native monkey flower (not WCA Schedule 9))

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 - If building B3 (Appendix C) is to be affected by the Scheme, further assessment of its suitability to support roosting bats should be carried out, as it has been assessed as providing high potential to support bats. Further surveys will include a daytime assessment to identify internal and external features that may support bats, and an inspection for evidence of roosting bats including droppings and feeding remains. Following the daytime assessment, further nocturnal bat roost surveys may be required to inform potential licensable mitigation works. It is assumed that trees on the right bank will be affected to facilitate the downstream connection of the bypass channel, and other trees on the right bank may also be affected for upstream connection. A Preliminary Roost Assessment survey of any trees to be impacted by the Scheme will identify potential roost features and establish the requirement for further surveys for roosting bats and subsequent licensing.
- Otter and water vole - A pre-works check for otter, which are well established in the River Dee in this area (and water vole in the unlikely event that they are present), including any areas to be affected by vegetation clearance and the connections of the bypass channel and up to a 50m buffer up and downstream, 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 - A pre-works check for badger in the immediate vicinity of the proposed works, in areas of proposed vegetation clearance and a 30m buffer, 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 30m of the proposed works and inform any required mitigation and licensing.
- 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.

4.1.7 Heritage

A study area comprising the Site and a 500m study area from a central point within Horseshoe Falls 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 (bypass channel) was undertaken and is provided in Appendix D.

The study found the following:

- Designated heritage assets included:
  - Pontcysyllte Aqueduct and Canal World Heritage Site
  - Pontcysyllte Aqueduct and Canal Scheduled Monument and Horseshoe Falls (Grade II listed)
  - Llantysilio Conservation Area
  - Vale of Llangollen and Eglwyseg Registered Landscape of Special Historic Interest
  - Llantysilio Hall Garden Registered Historic Park and Garden (Grade II listed)
  - Bryntysilio Registered Historic Park and Garden (Grade II listed)
  - Church of St Tysilio (Grade II listed*) including the churchyard, Pickering Monument (Grade II listed), Jones Chest Tomb (Grade II listed), Jones Monument (Grade II listed), Roberts Monument (Grade II listed) and Lychgate (Grade II listed)
  - Llantysilio Hall (Grade II listed *) including lodge (Grade II listed), walled garden (Grade II listed) and sundial (Grade II listed)
  - Bryntysilio (Grade II listed)
  - Berwyn Railway Station (Grade II listed)
  - Railway Viaduct (Grade II listed)

  - The Kings Bridge (Grade II listed)

- The setting of some designated heritage assets were defined by their position overlooking the River Dee; however, the proposed works would serve as an extension to the existing river infrastructure, including the weir and canal feeder, and therefore the overall character would not be considered to be altered. The proposed works would not result in physical impacts, nor change, to the setting of any designated heritage assets that would result in any loss of heritage significance. However, it should be noted that this does not include consideration of the notch which is part of the United Utilities / CRT eel screening scheme.
- The creation of the bypass channel and activities associated with its construction would result in physical impacts within the Site. It was concluded that there is a medium potential for heritage assets dating to the post-medieval and modern periods to be located within the Site. The proposed works have the potential to impact previously unknown archaeology relating to the post-medieval and modern periods, in particular remains associated with the construction of Horseshoe Falls and the associated later water works building, as well as the possible remains of an earlier post-medieval building. The proposed works also have the potential to impact previously unrecorded archaeological remains from all periods within the Site.
- There may be some ground disturbance within the Site related to the construction and demolition of a post-medieval building which is known to have existed within the Site, however the exact nature and depth of this disturbance is currently unknown.
- The Historic Landscape Character of the Site is defined as pasture land with a modern field boundary and building and is not considered sensitive to change.
- Due to the Site being located within the ‘essential setting’ buffer zone of the World Heritage Site and the Site’s close proximity to a Scheduled Monument, a Heritage Impact Assessment will be required to support planning consent, once detailed design of the proposed works is known. When developing detailed design for the proposed works, consultation with Cadw should be undertaken at an early stage.
- A proportionate and targeted programme of archaeological investigation may be required by the Development Control Archaeologist for Denbighshire County Council (DCC). This will likely be in the form of archaeological monitoring of any intrusive works within the Site, however this will need to be agreed with the Development Control Archaeologist for DCC. The scope of any archaeological investigation would need to be discussed with the Development Control Archaeologist for DCC and set out in a Written Scheme of Investigation (WSI) which would need to be approved in writing by the Development Control Archaeologist for DCC.

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 500m and 350m from the weir, respectively. The survey was undertaken to refine representation of the system within the hydraulic modelling (see Section 4.2.1).

All surveyed points are indicated in Figure 4-1 below while those around the weir itself are indicated in Figure 4-2, which shows a reasonable coverage with some gaps where surveying could not be undertaken safely.

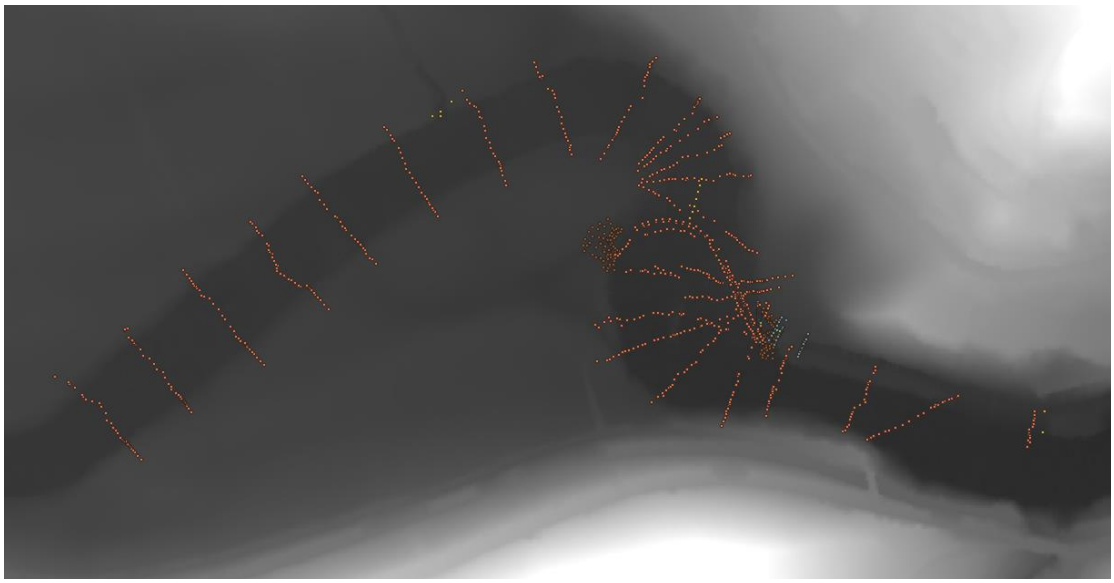


Figure 4-1. Horseshoe Falls weir xyz data received

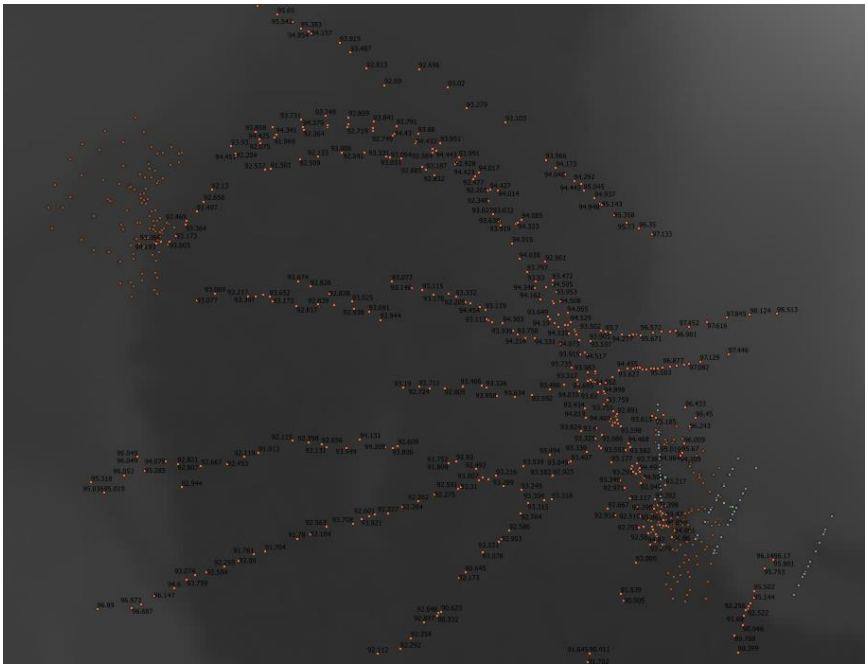


Figure 4-2. Horseshoe Falls weir xyz data received (zoomed into area around the weir)

The difference between all surveyed river points and LiDAR data is shown in Figure 4-3. This suggests that differences were generally within 1m, though upstream of the weir a deeper central channel was picked up by the survey but not the LiDAR (which is as expected, with water refracted LiDAR rays), again showing the value of undertaking the survey.

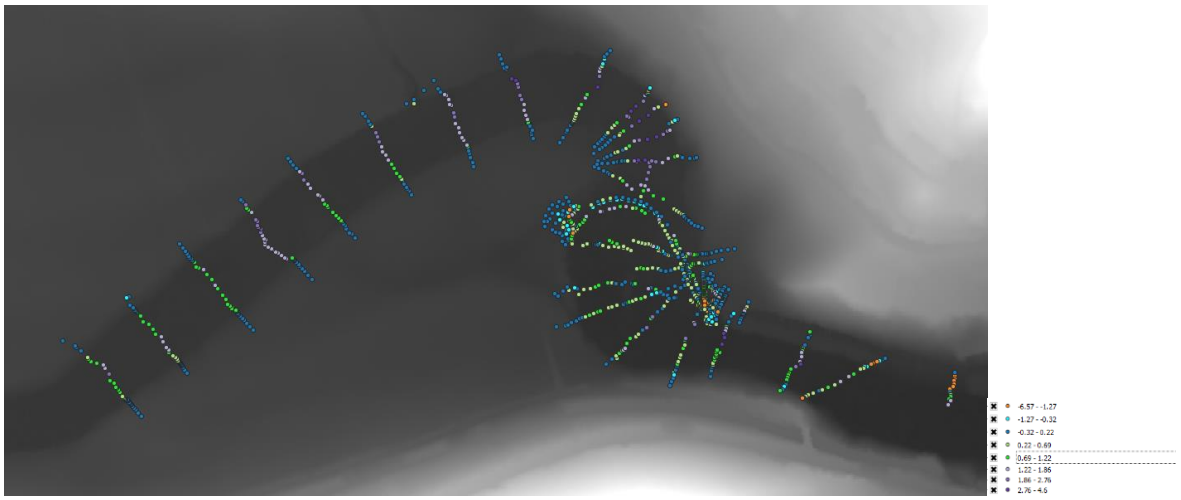


Figure 4-3. Differences between LiDAR and survey xyz data (LiDAR minus survey)

4.2 Design

4.2.1 Hydraulic Design and Fish Passage Review

Due to the anticipated flow constraints being present at the site, the optioneering process initially required empirical water level analyses to be undertaken (Section 4.2.1.1), followed by baseline model development (Section 4.2.1.2) and design scenario assessment (Section 4.2.1.3).

4.2.1.1 Empirical Water Level Analyses

As outlined in the Baseline Conditions, Horseshoe Falls weir is reported to be flow sensitive. The abstraction to Llangollen Canal is measured just downstream of the offtake, although this information has not been obtained and reviewed in support our concept design. We have obtained licence conditions however, and the impact of the maximum daily abstraction of 0.96m^3/s has been considered (as the maximum has been considered it represents a worst-case scenario). It should be noted that there may also limitations on flow conditions relating to when abstraction may occur, e.g. there may be hands off flows, designed to prevent abstractions at times of low flow, below which abstractions might not be permitted.

Given the flow sensitivity, in addition to hydraulic modelling, we have undertaken empirical flow analyses to support our assessment. Estimates of flow at the weir and through the different flow paths can be calculated, via the sharp crested weir equation[21]:

$$Q=2/3*C_d*b*\sqrt{2g}*H^{3/2}$$

in which Q is discharge, b is the weir width, H is the upstream head, g is gravitational acceleration and C_d is the discharge co-efficient. This approach is considered suitable for this initial analysis and it is noted that this may not fully predict flow amounts.

The water level analysis for the baseline is presented in Figure 4-4 below. Structural levels were informed by the topographical survey while flow estimates were as outlined in Table 3-2. Results show that flow occurs over most of the weir even at times of very low flow and that the weir crest is relatively uneven, providing further evidence that its condition is not pristine.

[21] Bos, M.G. (1989). Discharge measurement structures. Wageningen: International Institute for Land Reclamation, ILRI. Which is the Pub20.pdf.

Figure 4-4. Baseline Water Level Analyses

A review of levels with the maximum abstraction occurring was also undertaken. A comparison of the results of this against is provided in Table 4-5. Results show a minimal reduction in levels even with maximum abstraction occurring, suggesting that the wide width of the weir, compared to the channel width buffers any significant effect of the abstraction on levels over the weir.

Table 4-5. Comparison of Modelled Levels between Baseline (no abstraction) and Baseline (max abstraction)

Level statistic	Baseline (no abstraction) Level (m AOD)	Baseline (max abstraction) Level (m AOD)
H_{99}	94.52	94.51
H_{95}	94.53	9452
H_{70}	94.55	94.54
H_{50}	94.61	94.60
H_{30}	94.69	94.69
H_{15}	94.80	94.79
H_{10}	94.85	94.85
H_{5}	94.94	94.94

4.2.1.2 Baseline Modelling

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

A baseline model was constructed (with a Digital Elevation Model [DEM] being produced using the survey data that was collected in and around the weir). A number of flow scenarios were then run. Plots of depths between the runs for a low flow (Q_{95}) are indicated in Figure 4-5. A potential paleo-channel through the fields to the west of the bypass is also evident on this figure.

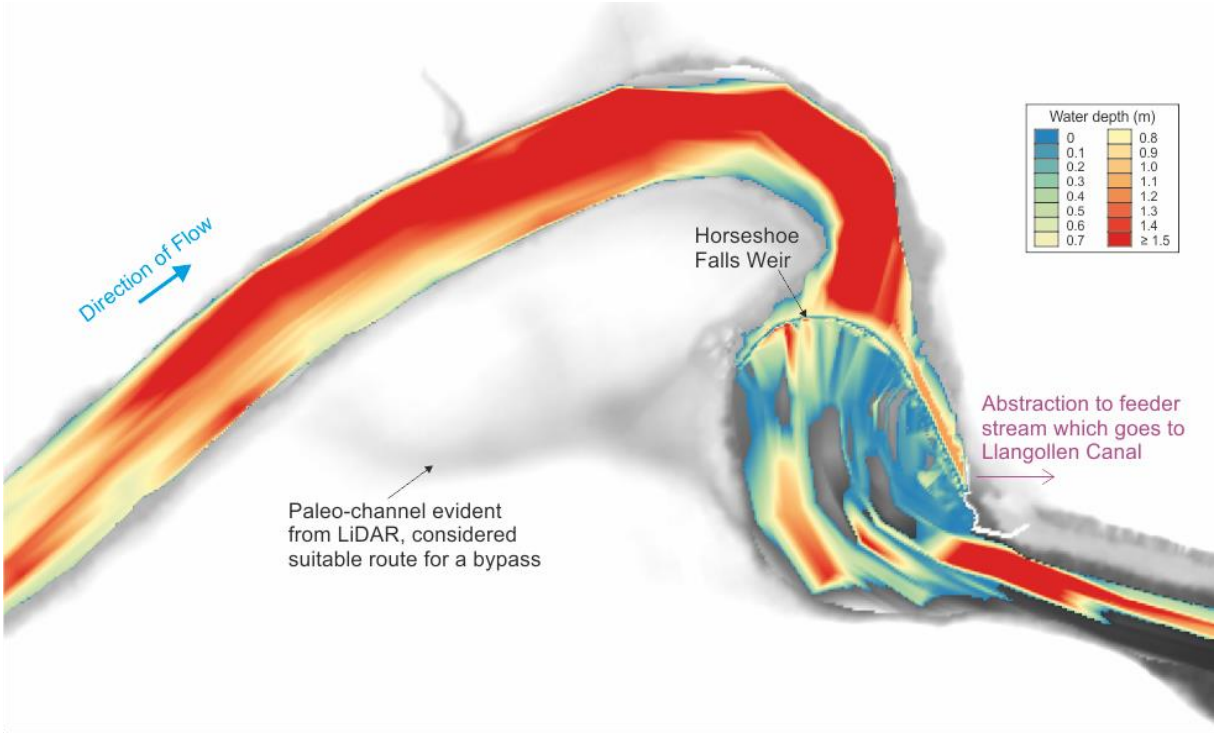


Figure 4-5. Baseline modelling depths at Horseshoe Falls weir (Q_{95} and underlain by a DEM)

4.2.1.3 Design Scenario

A design to improve connectivity at Horseshoe Falls weir was developed. The preliminary preferred option under consideration by NRW was a nature-like by-pass channel in the RHB to improve ecological connectivity. 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 Horseshoe Falls weir fish passage improvement design included:

- Improved passage primarily for upstream and downstream migrating salmonids, lamprey and eel across a range of flows
- Historic importance and designations
- Limited visual impact including avoidance of weir drying at low flows
- Canal abstraction (LHB) must not be impacted
- No increase to public safety risk or flood risk
- Maintenance

The preliminary preferred option would improve general ecological connectivity, including for the target species, and cause no increase to public safety risk or maintenance. A bypass in the RHB was considered preferable compared to other options for fish passage e.g. technical and other non-technical options for the broad range of target species and life stages, including eel and lamprey, and is therefore the recommended option at this site.

United Utilities and partners are currently assessing the feasibility of installing new screens just upstream of the weir and on the LHB side, to prevent eel entering the canal feeder stream from the River Dee, via the offtake. Their current plans are to include a small notch downstream of the weir (1.0 m wide and 0.2 m deep) to reduce trash that may gather at the screen. They have examined alternate sizes of notches and note the flow sensitivities at the site. A notch in the weir crest could also benefit the passage of downstream migrating smolts. The notch would ideally be positioned in line with the thalweg to enable efficient location by smolts[22]. However, the location of the notch for the screens would be positioned away from the natural thalweg and next to the intake screens, making this location less than ideal for smolt passage. Nevertheless, it was decided to undertake sensitivity testing as to the potential effects of this in combination with a bypass channel. If both are found to be suitable in combination but a notch was not ultimately included in the CRT scheme, our modelling process would demonstrate that a similar sized notch elsewhere in the weir might be possible (subject to additional consideration such as visual and heritage impact). In addition, sensitivity analyses as to the effects of a maximum CRT abstraction were also undertaken. Provision of a dedicated eel and lamprey pass on the LHB was considered inappropriate due to proximity of the canal intake.

A model comprising a bypass channel on the RHB was constructed and iterated until its performance was considered suitable. The final bypass route in the model DEM is shown in Figure 4-6 below. Its final length exceeded 220m while the drop in level between the top and bottom of the bypass is 1.6m (representing a gradient of 0.72%). The channel had a width of approximately 1.5m.

[22] Thorstad, E.B., Whoriskey, F., Uglem, I., Moore, A., Rikardsen, A.H. and Finstad, B., 2012. A critical life stage of the Atlantic salmon *Salmo salar*: behaviour and survival during the smolt and initial post-smolt migration. *Journal of Fish Biology*, 81(2), 500-542.

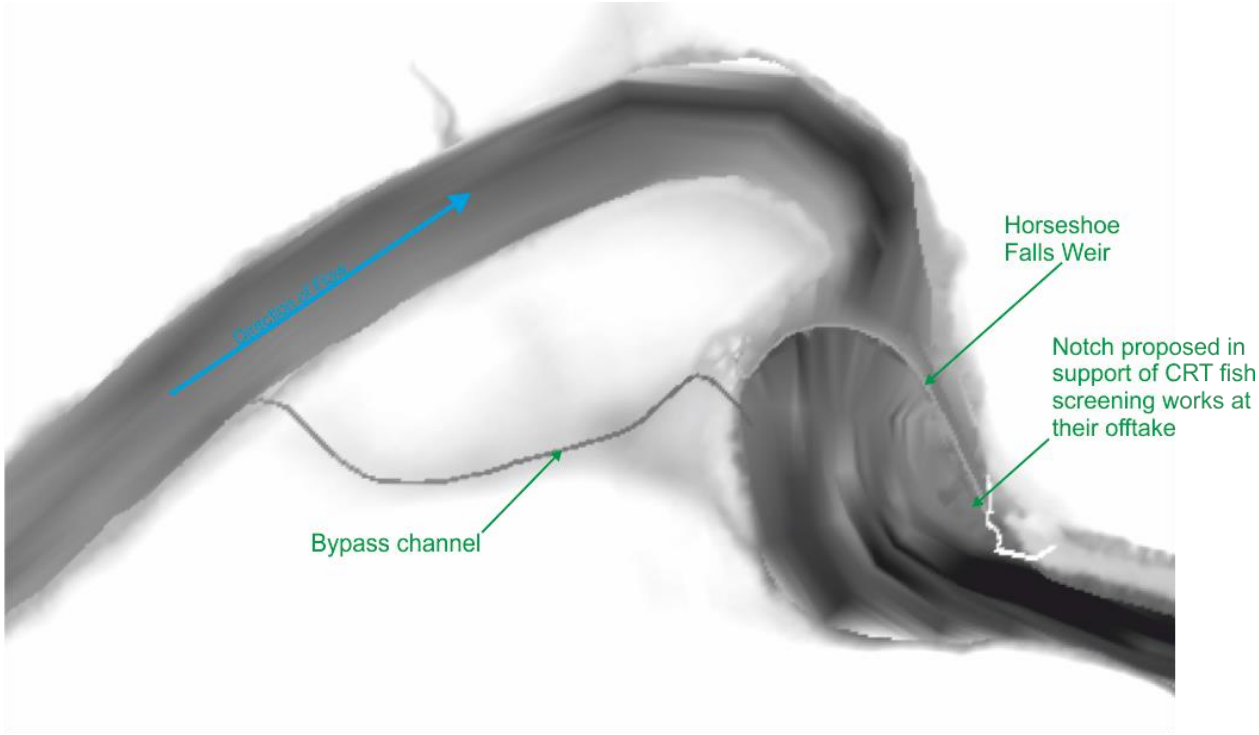


Figure 4-6. DEM for the bypass channel Horseshoe Falls weir scenario

Plots of velocities and depths for various flows under the baseline, bypass and notch scenarios are presented in Figure 4-7 and Figure 4-8, respectively. Approximate maximum water depth and velocity ranges at Q_{95} - Q_{10} (Table 4-6) in the bypass was sufficient for a range of target species and life stages[23]. Bypass substrate should be suitably selected based on geomorphological considerations and requirements for fish passage for all target species and life stages. Should the notch option also be taken forward, detailed design should ensure that flow accelerates gradually and smoothly into a bell mouthed notch entrance to assist the passage of downstream migrating smolts, and that canal intake screening complies with best practice guidance[24]. Discharge from the bypass constituted 2.5%, 3.3% and 7.3% of Annual Daily Flow (ADF) under Q_{95}, Q_{50} and Q_{10} scenarios, respectively. Best practice guidance suggests a minimum target discharge of 5% ADF for fish attraction to a route of passage, however, the guidance also notes that there can be no prescriptive definition of discharge requirements and that these will be dependent on site specific factors[23].

[23] 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.
[24] Environment Agency, 2005. *Screening for intakes and outfalls: a best practice guide*. Science Report CS030231. Environment Agency, Bristol, 153 pp.

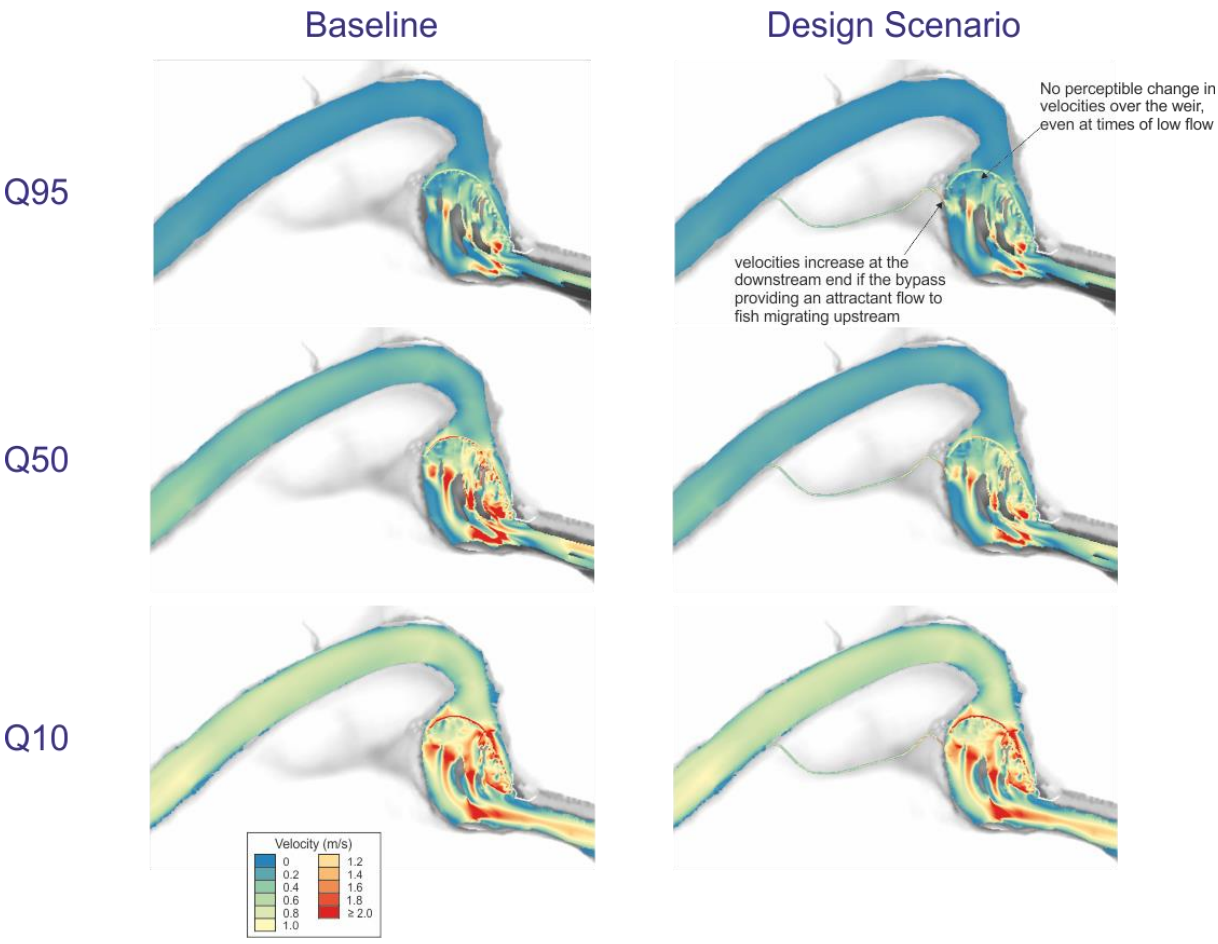


Figure 4-7. Velocity results for various flows under the baseline and design (bypass and 0.2m deep x 1.0m wide notch) scenarios

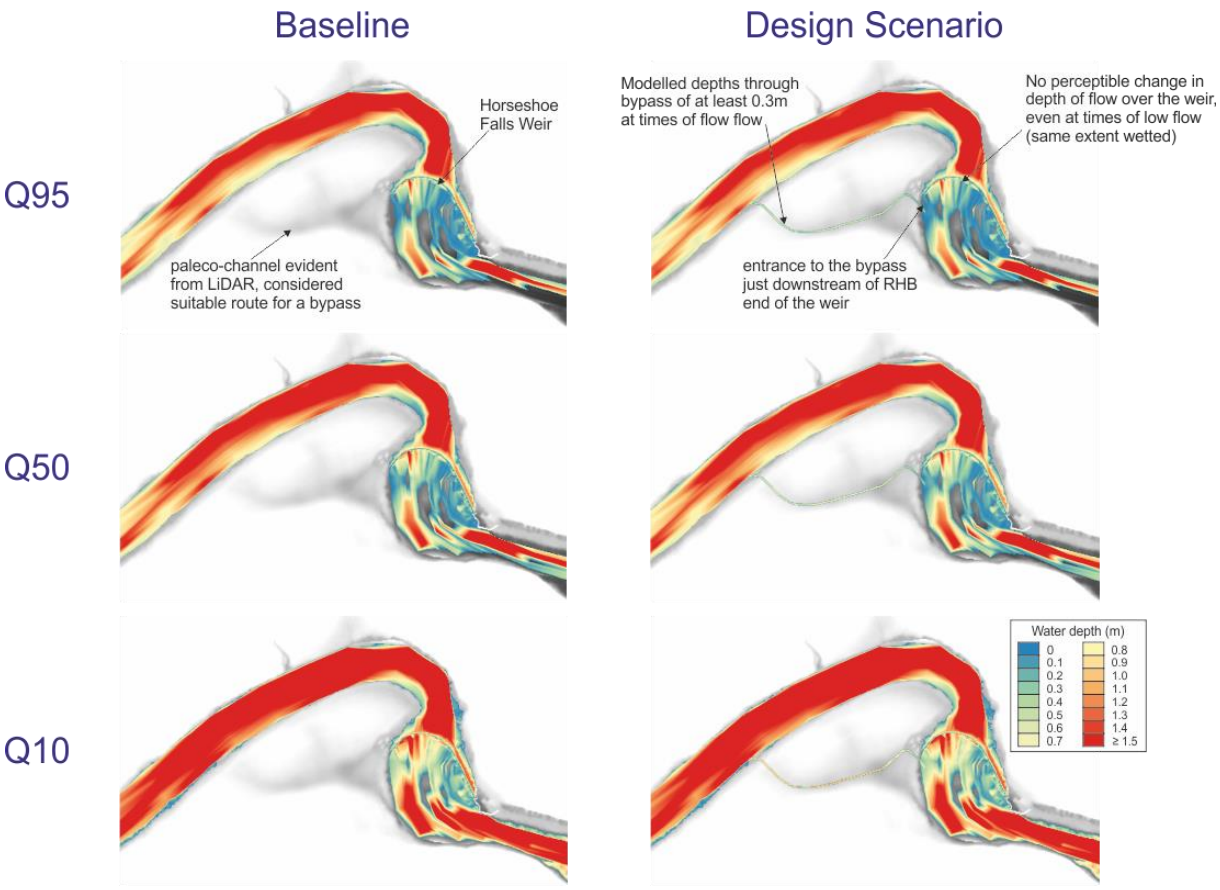


Figure 4-8. Depth results for various flows under the baseline and design (bypass and 0.2m deep x 1.0m wide notch) scenarios

Table 4-6. Approximate maximum design (RHB bypass and LHB 0.2m deep x 1.0m wide notch) scenario velocity and depth ranges through the bypass channel at Q_{95}, Q_{50} and Q_{10} flows

Flow statistic	Velocity (m/s)	Depth (m)
Q_{95}	1.6	0.2 – 0.6
Q_{50}	1.8	0.3 – 0.8
Q_{10}	2.0	0.4 – 1.2

No change in the extent or depths of flooding is predicted other than where the dimensions of the weir itself are altered and along the proposed bypass (see Figure 4-9).

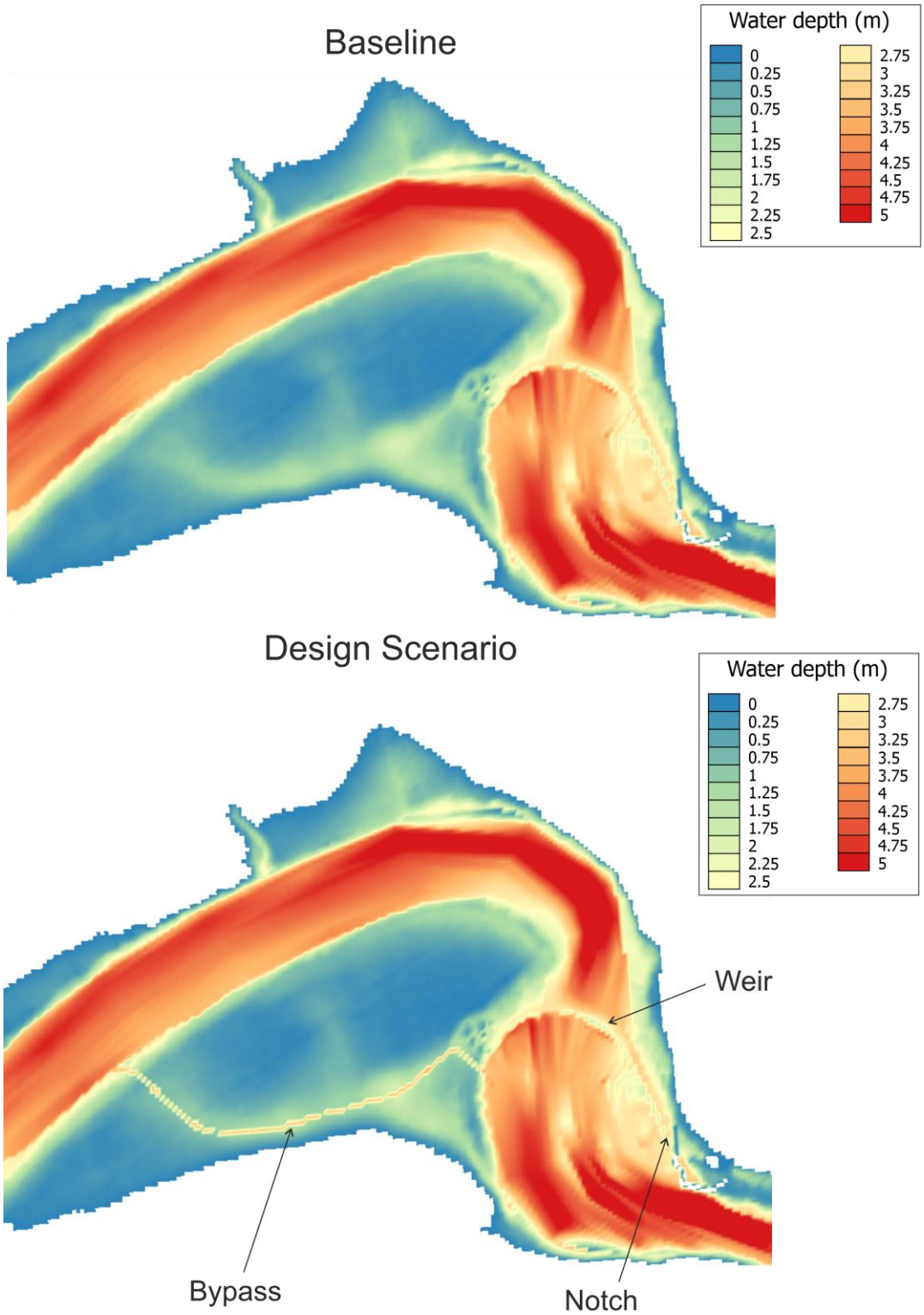


Figure 4-9. 1 in 100 year flood extent (plus climate change) for Baseline and Final Scenario

Results of the sensitivity analyses are presented in Figure 4-10 and Figure 4-11. Results for low flows have been presented as the site is considered to be flow sensitive. Results indicate that with maximum abstraction to the Llangollen canal offtake, the bypass should enable fish passage opportunities for multiple species. This is also the case with a small notch included, as is currently being investigated by United Utilities and partners in tandem with potential screen replacement works. This size of the notch may not considerably improve smolt passage, particularly given its location, but does demonstrate that both schemes should be compatible.

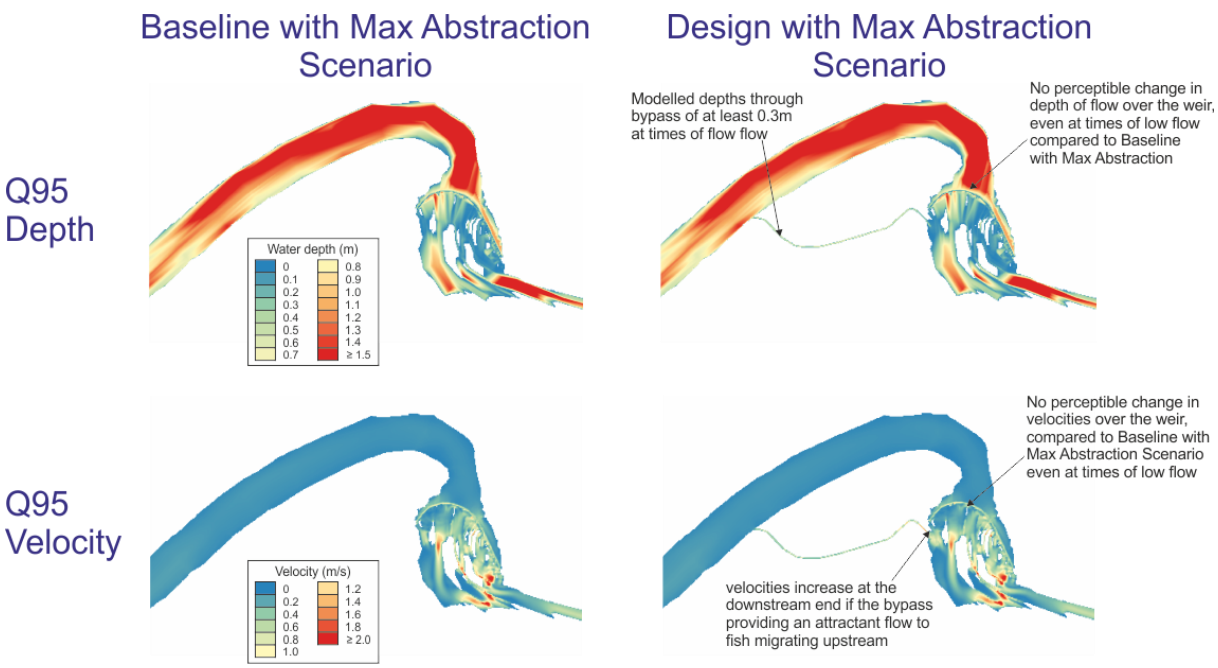


Figure 4-10. Comparison of Baseline and Design Max Abstraction Scenarios (Q_{95} depth and velocities)

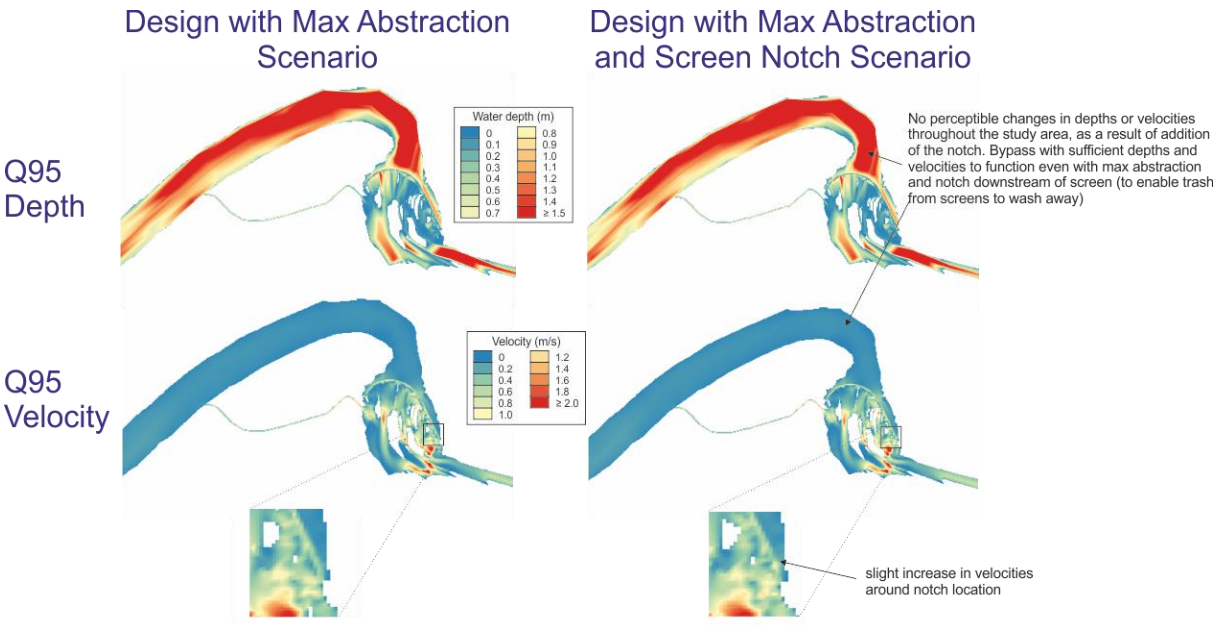


Figure 4-11. Comparison of Design Max Abstraction and Design Max Abstraction with United Utilities / CRT Notch Scenarios (Q_{95} depth and velocities)

4.2.2 Design Schematics and visualisations

4.2.2.1 Access and Utilities

An access and utilities plan was produced and is show in Figure 4-12. Full service results for the site are included as Appendix E.

Utility records indicate that there is an electricity cable and water mains running through the path of the proposed bypass.

As expected for an urban setting, a number of discharges enter the Dee in the study area. None of these are located in the vicinity of the weir itself from the south bank (from which access is anticipated, as discussed in the following section).

4.2.2.2 Plan of the works

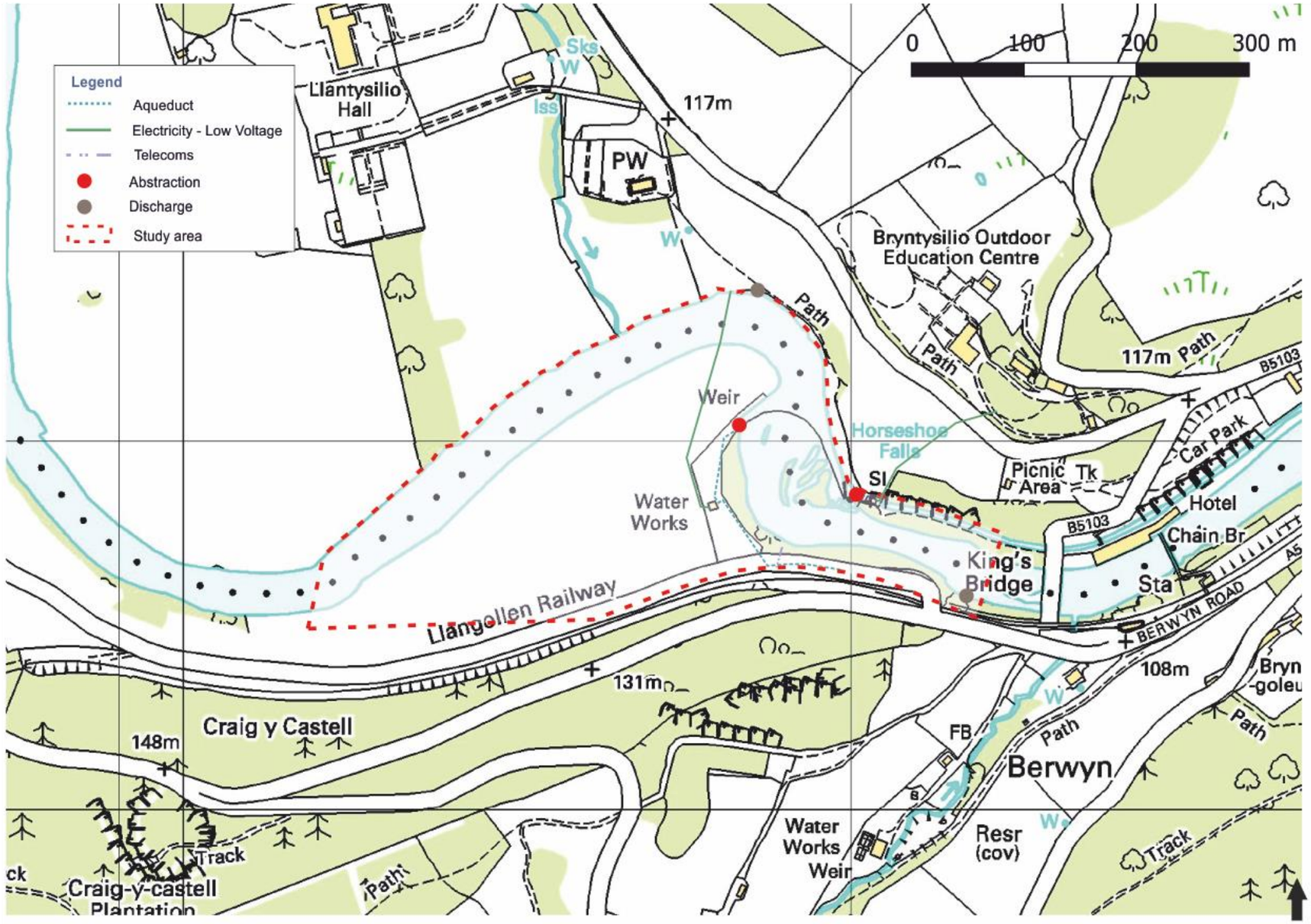
An indicative plan of the works and working area is provided in Figure 4-13.

4.2.2.3 Long Section and Cross Sections

Various sections (long and cross sections), indicating baseline and partial removal DEM levels as well as water levels under various flow scenarios are provided in Figure 4-14.

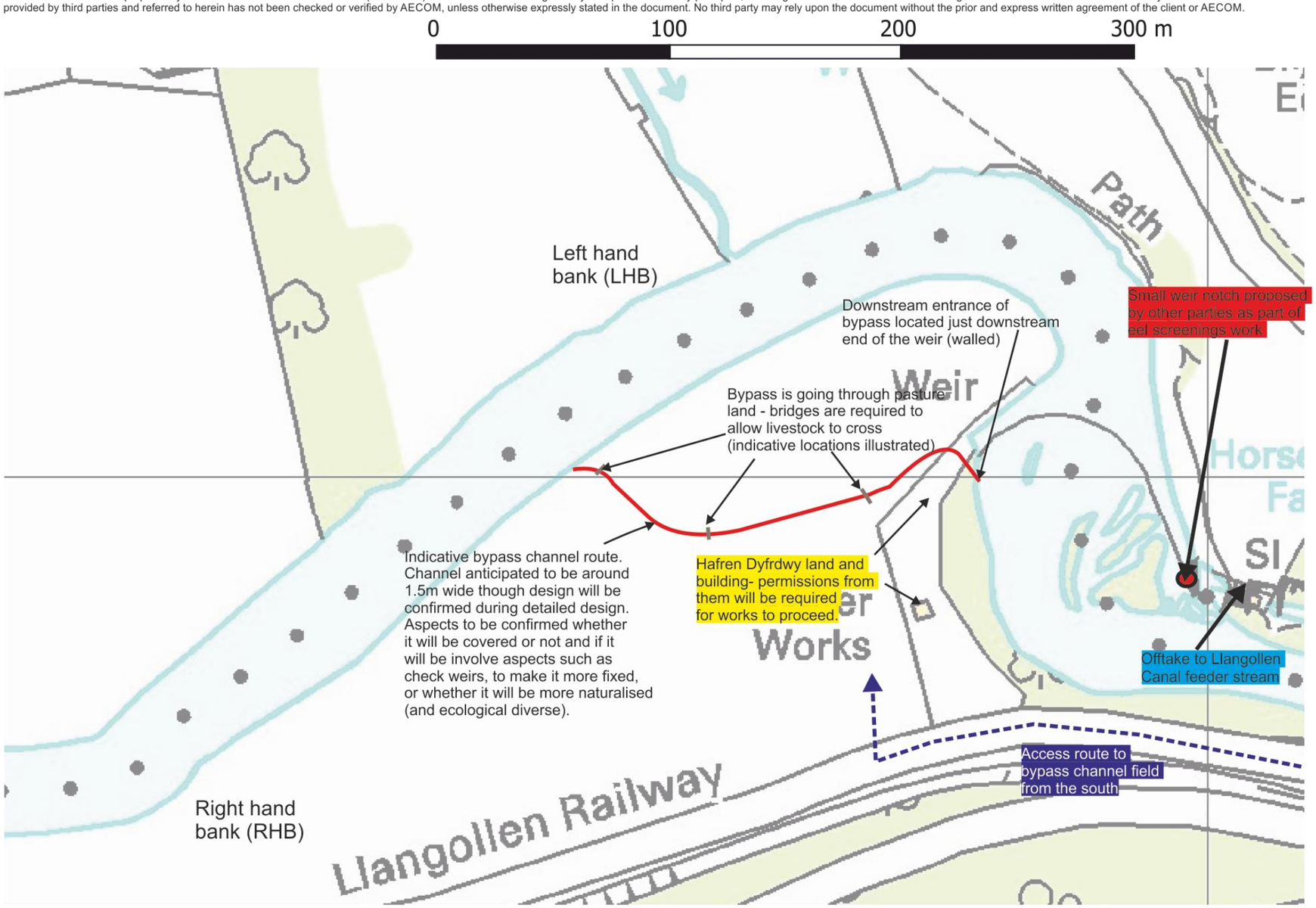
Not for construction

Notes



Natural Resources Wales (NRW)	Cyfoeth Naturiol Cymru Natural Resources Wales / AECOM	Drawn: PM	Checked NE
Project: NRW Dee (LIFE) Restoration of Freshwater Features project	1 New York Street, Manchester	Approved: RC	Verified: OS
Title: Horseshoe Falls Weir Utilities	Tel: +44 (0) 161 601 1700 www.aecom.com	Drawing Number: HF.1	Version Number: 1

Figure 4-12. Utilities Plan in study area around Horseshoe Falls weir



Not for construction

Notes

Location of a site compound and access routes to be determined and would require local landowner permissions.

Existing weir is dilapidated. Structural surveys should be undertaken during detailed design to inform the final design (while further testing in dry conditions/ during works may also be required).

Ground conditions of bypass route and access unknown - further investigations are required in advance of any works.

Utilities are present under the proposed bypass. Depth fo these should be investigated to confirm final design.

Horseshoe Falls Desk-Based Heritage Assessment was undertaken for the preliminary option (bypass channel) and prior to consideration of a notch. Heritage should be considered further should the option of a notch be taken forward.

Site is a World Heritage Site and near a Scheduled Monument. A Heritage Impact Assessment will be required to support planning consent. Consultation with Cadw should be undertaken at an early stage.

Archaeological investigation may be required by the Development Control Archaeologist (DCA) for Denbighshire County Council (DCC), and the scope should be discussed with DCC DCA and set out in a Written Scheme of Investigation for approval.

Consult relevant statutory bodies to undertake Habitats Regulations Assessment screening, to determine need for Appropriate Assessment.

Impacts to semi-natural broadleaved woodland, semi-improved grassland and tall ruderal vegetation should be minimised and reinstated to a similar or higher ecological value upon completion of the works.

The bypass channel area may be subject to a 5-year management plan to ensure habitats establish satisfactorily to replace habitats lost, to be agreed with LPA.

A Preliminary Roost Assessment (PRA) survey of any trees be impacted and Building 3 will establish the requirement for further surveys for roosting bats and subsequent licensing.

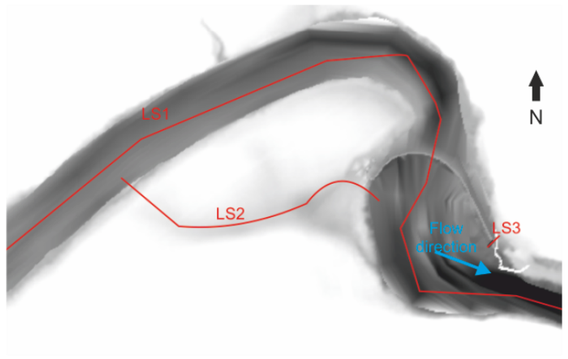
Pre-works checks would also be required for otter, water vole, badger and INNS to inform mitigation and licensing requirements. Vegetation clearance is recommended between April and September.

INNS were noted in the desk study and/or during the site visit and should be duly accounted for.

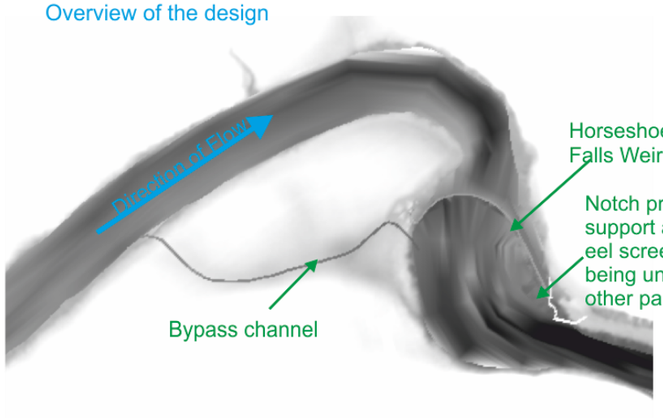
Client: Natural Resources Wales (NRW)	Cyfoeth Naturiol Cymru Natural Resources Wales / AECOM 1 New York Street, Manchester Tel: +44 (0) 161 601 1700 www.aecom.com	Drawn: PM	Checked: GW
Project: NRW Dee (LIFE) Restoration of Freshwater Features project		Approved: OS	Verified: OS
Title: Horseshoe Falls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

Figure 4-13. Indicative Plan of Works around Horseshoe Falls weir

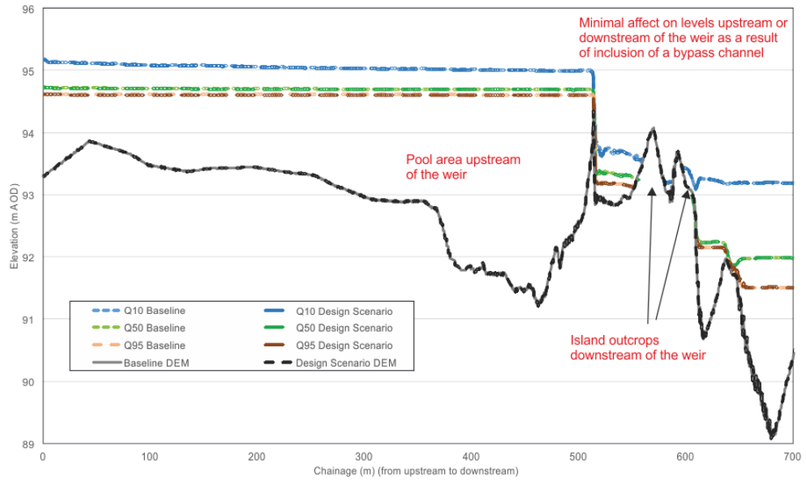
Location of sections



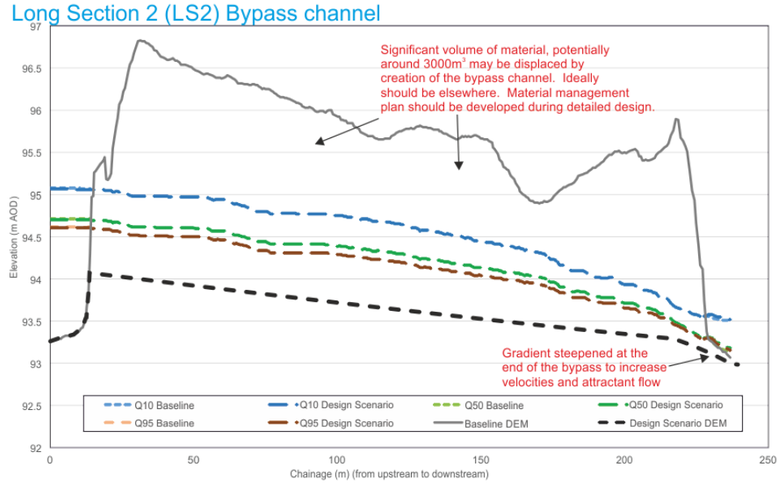
Overview of the design



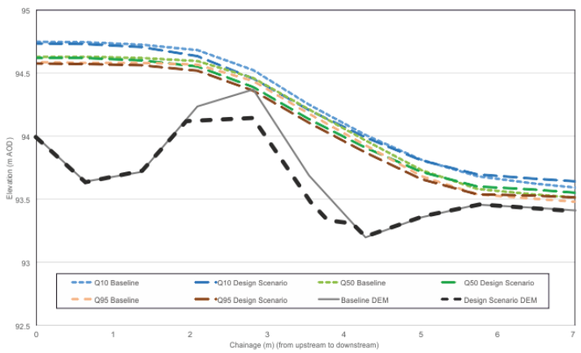
Long Section 1 (LS1) Main channel



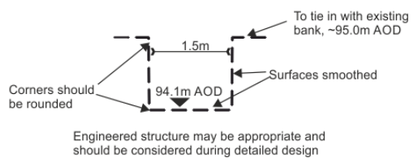
Long Section 2 (LS2) Bypass channel



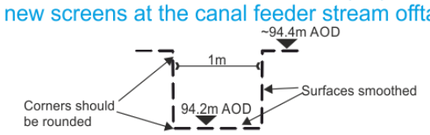
Long Section 3 (LS3) Weir Notch



Schematic of invert details at top of the bypass channel



Schematic of notch downstream of proposed new screens at the canal feeder stream offtake



Not for construction

Notes

Creation of a bypass channel may result in around 1,600m^3 of material being moved. Ideally this would be used elsewhere on site subject to material testing and could be used for landscaping purposes.

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: GW
Project: NRW Dee (LIFE) Restoration of Freshwater Features project		Approved: OS	Verified: OS
Title: Horsehose Falls Weir long sections and cross sections		Drawing Number: HF.3	Version Number: 2

Figure 4-14. Long section and channel sections showing Baseline and Design scenario DEM levels and water levels for various scenarios plus other design details (Horseshoe Falls weir)

5. Next Steps and Recommendations

Modelling has confirmed the suitability of a bypass channel for fish passage on the RHB at Horseshoe Falls weir, including an indicative route. Sections 5.1.1 and 5.1.2 summarise key next steps and recommendations.

5.1.1 Detailed Design

Hydromorphology

The study has confirmed the suitability of a bypass channel as a fish pass at the site and an indicative route has been shown. Detailed design should account for, amongst others, the following:

- Bed and bank materials.
- How naturalised the system is (i.e. should it include varied geomorphic features or be more controlled through inclusion of engineered solutions such as checked weirs). A more varied system could provide multiple passage routes for species and wider environmental benefits.
- Access bridges, for livestock and people.
- Whether formal structures, particularly at the upstream exit and downstream entrance, are included. These could reduce the risk of significant unwanted geomorphological changes such as knickpoint erosion.

Services

- Utilities are present under the path of the proposed bypass channel. Depths should be determined, through consultation or techniques such as Ground Penetrating Radar, to inform the final route and design as well as confirm feasibility.

Ground Condition and Contaminated Land

- If a bypass channel is progressed, a series of window samples holes should be carried out in the main on site field. The window samples should be progressed in order to determine physical, from a geotechnical perspective, and chemical properties of the superficial deposits and to determine the depth of rock head which may impede the construction of the bypass channel. The window samples should be carried out to refusal or to where a defined water table is found. The obtained groundwater level can be used to determine on site groundwater deposits feed into the River Dee. Window samples should also be carried out as close to, or if it is permitted, on the land where the pump house is located to determine if made ground is present should the proposed bypass channel be designed in close proximity of the pump house. In addition to these locations, some window samples should be progressed as close to the south boundary of the on site field as possible. These locations will aid insight to if any potential off site contamination, associated with the railway, is migrating on site. Environment samples will be taken of the soils and shallow strata to give insight on the presence and concentrations of CoPCs associated with the land use. Geotechnical samples should also be collected to determine the suitability of the ground for the proposed bypass channel. Other onsite geotechnical tests should be carried out to determine suitability for the access road.
- Surface water samples should be taken on the River Dee. 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.
- Creation of a bypass channel may result in around 1,600m^3 of material being moved. Ideally this would be used elsewhere on site subject to material testing and could be used for landscaping purposes.

Ecology

- 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;

- 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 and on the vegetated islands downstream of the weir is identified as woodland Priority Habitat, and any losses of this habitat should be replaced on a like-for-like basis.
- Areas of semi-improved grassland and tall ruderal vegetation are also of high ecological value for a range of species, and similar areas of these habitats to those lost should be built into the design of the Scheme. Areas of poor semi-improved grassland to be lost through the creation of the bypass channel should be compensated for by the creation of habitats of higher ecological value such as semi-improved grassland and broadleaved woodland.
- Habitats created through the Scheme, including the bypass channel and associated habitats, should be subject to an on-going management plan to ensure that they establish satisfactorily to replace habitats lost. The management plan should cover a period of five years from completion of the Scheme, unless otherwise specified by the Local Planning Authority.

Heritage

- Due to the Site being located within the 'essential setting' buffer zone of the World Heritage Site and the Site's close proximity to a Scheduled Monument, a Heritage Impact Assessment will be required to support planning consent, once detailed design of the proposed works is known. When developing detailed design for the proposed works, consultation with Cadw should be undertaken at an early stage.
- The works also offer the opportunity to repair the existing weir structure, improving the overall condition.

Fish Pass Design

- Bypass substrate should be suitably selected based on geomorphological considerations and requirements for fish passage for all target species and life stages.
- If a notch is progressed, detailed design should ensure that flow accelerates gradually and smoothly into a bell mouthed notch entrance to assist the passage of downstream migrating smolts. A pool immediately downstream of the notch may be required. A minimum depth of 0.9m for head differences of <3.6m is suggested, however refinement based on local constraints may be possible.
- The abstraction to Llangollen Canal is measured just downstream of the offtake, and this information, including licence conditions, should be obtained and reviewed to inform detailed 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.

5.1.2 Other

Ground Condition and Contaminated Land

- Upon completion of the fish bypass channel, surface water samples should also be taken of the channel. This should be done on only if the bypass channel is excavated through Made Ground (potentially near the pump house) or if it is expected that there are non-natural inputs to the channel. If determined necessary, sampling should be carried out on at least three occasions post completion, reduced if no concerns are raised from the lab analysis. This will not necessarily aid any insight for the reassessment of current pollutant linkages, however, will be useful to monitor the water quality of the new channel and any changes in chemical composition.
- Considerations should be taken as to what waste is produced, how it is stored and methods of disposal. Dependant on the outcome, classification of wastes may be required if offsite disposal is to be considered.
- There should be a further detailed assessment of the mining risks in the area as a result of the localised small-scale underground mining of a vein mineral that occurred in the area. This assessment should be carried out prior to any intrusive works carried out.

Ecology

- Further assessment of the suitability of an existing building (building B3) on site to support roosting bats should be carried out, as it has been assessed as providing high potential to support bats. Further surveys will include a daytime assessment to identify internal and external features that may support bats, and an inspection for evidence of roosting bats including droppings and feeding remains. Following the daytime assessment, further nocturnal bat roost surveys may be required to inform potential licensable mitigation works. It is assumed that trees on the right bank will be affected to facilitate the downstream connection of the bypass channel, and other trees on the right bank may also be affected for upstream connection. A Preliminary Roost Assessment (PRA) survey of any trees to be impacted by the Scheme will identify potential roost features and establish the requirement for further surveys for roosting bats and subsequent licensing.
- Pre-works checks relating to tree coppicing/removal and vegetation clearance would also be required for otter, water vole and badger to inform mitigation and licensing requirements. Vegetation clearance is recommended between April and September.
- INNS were noted in the desk study and/or 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

- A proportionate and targeted programme of archaeological investigation may be required by the Development Control Archaeologist for Denbighshire County Council (DCC). This will likely be in the form of archaeological monitoring of any intrusive works within the Site, however this will need to be agreed with the Development Control Archaeologist for DCC. The scope of any archaeological investigation would need to be discussed with the Development Control Archaeologist for DCC and set out in a Written Scheme of Investigation (WSI) which would need to be approved in writing by the Development Control Archaeologist for DCC.

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