DATA LABEL: PUBLIC

West Lothian Council

COUNCIL EXECUTIVE

RIVERLIFE: ALMOND & AVON – ALMOND BARRIERS PROJECT – MID CALDER WEIR

REPORT BY HEAD OF OPERATIONAL SERVICES

A. PURPOSE OF REPORT

The purpose of this report is to provide an update on progress, outline the issues that have arisen in development of the project to adapt Mid Calder Weir and afford Council Executive the opportunity to review its previous decision in favour of a partial rock ramp.

B. RECOMMENDATION

The Council Executive is recommended to:

1. Note the progress being made to adapt the weir at Mid Calder and the issues that have arisen;
2. Consider and approve a proposal to proceed with detailed design, procurement and construction of a Larinier-type technical fish pass on riparian land owned by the Council; and
3. authorise officers to commission work to determine the optimum location and technical design of the Larinier-type technical fish pass.

C. SUMMARY OF IMPLICATIONS

I	**Council Values**	Focusing on our customers' needs; being honest, open and accountable; providing equality of opportunities; making best use of our resources; and working in partnership.
II	**Policy and Legal (including Strategic Environmental Assessment, Equality Issues, Health or Risk Assessment)**	**Policy:** The Scottish Biodiversity Strategy identifies the role of local authorities in meeting national species and habitat priorities. **Legal:** The Water Environment & Water Services (Scotland) Act 2003 requires local authorities to carry out their statutory functions and duties in a way, which adheres to the principles of the European Water Framework Directive. The Nature Conservation (Scotland) Act 2004 places a duty on officials and public bodies to further biodiversity.

III	**Implications for Scheme of Delegations to Officers**	None
IV	**Impact on performance and performance Indicators**	Across Scotland river quality has improved significantly over the last 25-years and just under half of our rivers are now of good status. Ambitious targets have been set for rivers, with an objective for 87% to be at good or high-status by 2027. SOA1308-11 (% of water bodies achieving high or good status).
V	**Relevance to Single Outcome Agreement**	SOA 3.Our economy is diverse and dynamic, and West Lothian is an attractive place for doing business; SOA 8.We make the most efficient and effective use of resources by minimising our impact on the built and natural environment.
VI	**Resources - (Financial, Staffing and Property)**	**Financial:** Funding for RiverLife projects derives from the Scottish Government's Water Environment Fund (WEF) and National Lottery Heritage Fund (NLHF). **Staffing:** The Council is represented by officers on individual project groups and the RiverLife Project Board. The National Lottery Heritage Fund and Scottish Government provide additional resources to support the project through a number of pre-agreed activities discharged by River Forth Fisheries Trust. **Property:** The Council has riparian ownership, of the right (south) bank to the middle of the river.
VII	**Consideration at PDSP**	This report was considered by the Environment Policy Development & Scrutiny Panel on 10 March 2020. The Panel 91) Noted the content of the report; and 2) Agreed that the report and its recommendations be forwarded to the next appropriate meeting of the Council Executive for approval subject to addressing the inaccurate statement in paragraph 3.2 and including comments submitted by Mid Calder Community Council. These amendments have been made.
VIII	**Other consultations**	The following organisations and individuals have been consulted in work leading to preparation of

this report:

WLC Legal Services, Forth Rivers Trust (FRT), Forth District Salmon Fishery Board (FDSFB), Householders with left bank riparian ownership, Mid Calder Community Council (MCCC), Mid Calder Weir Project Group, RiverLife: Almond & Avon Project Board and the Scottish Environment Protection Agency (SEPA).

D. TERMS OF REPORT

1.0 Introduction

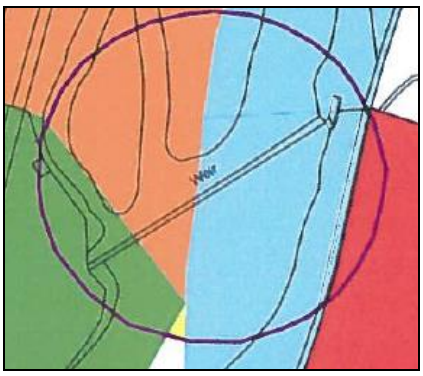
1.1 **RiverLife: Almond & Avon** - Members have previously heard about the RiverLife: Almond & Avon programme and within it, the Almond Barriers Project.

1.2 **Almond Barriers Project** - There are seven large weirs on the River Almond significantly impacting fish passage and being addressed under the project. It is critical for success that all of these barriers are adapted. West Lothian Council owns, part-owns and holds licenses under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 for five out of seven of the weirs. Adaptation has been successfully completed on three of these at Kirkton, Craigshill and Howden. Work will commence shortly at Limefield, Polbeth. The City of Edinburgh Council has adapted its weir at Fair-a-Far, Cramond and currently has a project in development to adapt Dowies Mill Weir, Cramond.

2.0 Mid Calder Weir

2.1 **Facts** - The weir at Mid Calder is a large structure, some 65 metres long and 2.5 metres high of concrete and cobble construction. Although it already has a two-flight box fish pass, this is not effective. The weir is considered the uppermost point for salmon and sea trout migration on the Almond, so successful adaptation would open-up considerably more spawning grounds for these species, to the upper main stem of the river and its tributaries.

2.2 **Ownership** - Property titles are silent regarding the weir, which was understood to have been constructed to provide a take-off to power the mill, originally located on land currently occupied by East Calder Wastewater Treatment Works. Legal advice suggests that the weir belongs to those that have riparian ownership. This view is accepted by officers, SEPA, and FRT and is one widely-held across the United Kingdom. The Council's riparian ownership extends from the right (south) bank into the bed of the river to its middle point (usque ad medium filum aquae), a rule in law when a boundary is formed by a non-tidal stream and the title extends to an imaginary line along the middle of the stream. The position regarding ownership and responsibility for the weir, however, it is not necessarily agreed by those householders, whose riparian boundaries from the left (north) bank extend to include parts of it.



Green – 3 Powies Path
Brown – 4 Powies Path
Blue & Red – West Lothian Council

(For those reading black and white version of report colours work from left (green) to right (red)

Fig. 01 – Extract from the Certificate of Title Showing Approximate Ownership

3.0 Adaptation proposals

3.1 **Current proposal** - In October 2016, the Council Executive approved a proposal to construct a partial rock-ramp across that part of the river at Mid Calder owned by the Council in order to provide a shallow incline to the top of Mid Calder Weir, which is to be retained. This would have been a similar solution to that recently completed at Howden, Livingston where a full-width rock-ramp was recently constructed. The decision favouring a partial rock-ramp was recommended by officers at the time, in the context of advice from independent consultants, dialogue with project partners and funders and followed an earlier decision favouring a Larinier (that study had considered options for full weir removal, partial removal or installation of a Larinier).

3.2 **Local concern** - The proposal for a partial rock ramp caused concern when presented to householders with left (north) bank riparian boundaries, which extend to include parts of the weir. Their principle concerns are based on mitigation of flood risk to their properties, which significant changes to the river may bring, the redirection of river flow, wildlife habitat and the industrial heritage of the village, all of which may be affected by the introduction of particular measures to provide fish passage. Their concerns had been exacerbated by an unintentional hiatus in communication; following handover of the project from RAFTS to the Council, which resulted in householders not having been kept informed that the original decision favouring a Larinier had been overturned.

3.3 **Consultation** - At a meeting in December 2018 attended by one set of householders, office-bearers from Mid Calder Community Council and a representative from Forth Rivers Trust, it was agreed to re-run the consultation events originally facilitated by RAFTS back in May 2015 on the basis that these did not include the proposal for a partial rock-ramp. Two drop-in sessions were arranged in February 2019, in Mid and East Calder. In the run-up to these events, Mid Calder Community Council (MCCC) issued leaflets, which encouraged local people to attend the drop-in sessions and respond to a separate Community Council online survey.

3.4 **Feedback** - Both drop-in sessions, staffed by representatives from WLC, FDSFB, FRT and SEPA, were well-attended. Written and verbal feedback from both events was overwhelmingly in support of the partial rock ramp. A number of specific technical issues were reiterated by householders with riparian ownership. Mid Calder Community Council later provided a summary of its own survey, which it claimed favoured a Larinier (61%) over a rock-ramp (39%).

3.5 **Critique** - There was criticism by householders of both the drop-in sessions and the Community Council's survey because they had been expecting consultation based on two possible options (partial rock-ramp and Larinier) and found only an exhibition based around a partial rock-ramp, which they claimed made it difficult to make an informed choice.

3.6 **Review of feedback** – following the events and survey, a meeting of project partners was arranged to review feedback. It was agreed that there were a number of specific actions, which required investigation in order to analyse and competently respond to the specific technical concerns raised by householders with riparian ownership. These related to ownership; to better understand how the proposal might affect the assets owned by others; a topographical survey in order that detailed design accurately represented current in-channel conditions; an understanding of the effect of proposals on flood risk, geomorphology and ecology.

3.7 **Further analysis** - an independent firm of consultants was commissioned to undertake the technical work necessary to inform analysis. A meeting was later arranged between officers, consultants and householders to discuss concerns and provide answers based on preliminary findings. As a result, the consultants' commission was extended to include objective review and analysis of potential alternatives to the partial rock ramp. The resulting draft reports were shared at an early stage with householders and feedback from all parties was taken into consideration before they were finalised.

3.8 **Findings** - The report 'Option Appraisal of Fish Passes at Mid Calder Weir' (Appendix 1) was completed in January 2020 and, in summary, came out in favour of a Larinier super-active baffled fish pass as a better adaptation option at Mid Calder Weir, taking into account the various site-specific constraints.

4.0 Deliberations

4.1 **Forth Rivers Trust's view** - Project partner, Forth Rivers Trust, supports the findings from the option appraisal but considers a partial rock-ramp a better option from an ecological and sustainability perspective. Larinier-type solutions are considered less effective at getting fish past obstructions than more nature-like structures. The Trust added that a technical fish pass may also be more difficult to manage from an operational perspective and may require additional resources from Forth District Salmon Fishery Board and Police Scotland should the structure become a target for wildlife crime.

4.2 The Trust added that if the Council intends to change its preference from a partial rock-ramp it should not at this stage opt for either of the two suggestions in the option appraisal without further integration of location, type of technical pass and possible solutions for other species. This is an once-in-a-lifetime chance to get the best solution. Further compromise is not considered acceptable. If it is to be a technical fish pass it has to be the best possible one. The Trust concludes that it doesn't wish to delay progress further and whilst it believes a technical solution such as a Larinier, sub-optimal, the project must move forward and find the best possible technical solution.

4.3 **SEPA's view** - The consultant was asked to balance a number of factors to refine the choice of option, essentially between partial rock ramp and a Larinier pass. The report's conclusion was that a Larinier (along with eel/lamprey channels) would meet the project requirements of passage for all target species over a range of flows. Any form of technical fish pass presents compromises. However, given that removal is not an option at Mid-Calder, SEPA accepts the report's findings and is content to progress on this basis.

Reflecting on Forth Rivers Trust's comments, SEPA would like the detailed design stage to work out the best choices of location and design for the Larinier and eel/lamprey passes for ensuring:

- Suitable passage for all target species
- Depth and velocities in the pass appropriate for passage at a range of river flows
- Suitable attraction flows at the Larinier mouth
- Minimisation of the potential for fish to miss the pass entrance

4.4 **Council officer's view** - Officers have an obligation to deliver a solution in a timeframe limited by the funding agreement with the National Heritage Lottery Fund (NHLF). Whilst a partial rock-ramp is considered more ecologically effective and aesthetically pleasing, it would be significantly less easy to deliver in the context of local opposition, particularly in conditions where impacts on the assets and amenity of others would be difficult to avoid.

4.5 **Householder's view** - in response to the consultant's option appraisal, the householders with riparian ownership have provided the following statement:

"After a considerable number of years of uncertainty and concern over the potential serious impact of options proposed previously for the weir at Mid Calder, the residents on the left bank of the river are delighted that the AECOM report recognises and upholds our concerns. As such, we are happy to support the proposal for a Larinier fish pass on the right hand bank of the river as this option will also cause less harm to the local habitat whilst achieving the aims of the project."

4.6 **Mid Calder Community Council's view –** Mid Calder Community Council has provided the following statement:

"We, as representing the residents of the village, we are delighted to note from your report that our concerns along with the concerns of those livings beside the River Almond have been listened to and taken into consideration".

"We are happy to support the proposed Larinier fish pass on the right-hand bank of the river as this option seems the best for the local habitat whilst still achieving the aims of the project".

E. CONCLUSION

RiverLife: Almond & Avon is an ambitious programme of work helping restore the natural heritage of our local rivers supported by community engagement activities.

The Almond Barriers project is the largest project within the programme aimed at adapting barriers across the Almond allowing migrating fish and other aquatic species to move freely from the sea to the upper tributaries.

Mid Calder Weir is currently considered the uppermost point for salmon and sea

trout migration and requires adaptation to allow fish to reach the upper tributaries of the river. The council is funded to deliver this project, which has been delayed by local concern, brought about by potential impacts and discontinuous communication.

Time and effort have been invested to investigate the specific technical concerns of householders and reappraise options based on technical criteria. The outcome of that process supports a Larinier-type technical fish pass at Mid Calder Weir.

This solution has the support of project partners subject to further consideration of its location and design. Householders and Mid Calder Community Council support the proposal subject to it being on, or close to, the right (south) bank of the river.

F. BACKGROUND REFERENCES

The Forth Invasive Non-Native Species Programme: Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 19 January 2012

Public Body Reporting on the Scottish Biodiversity Duty: 2011-2014 – Report by Head of Planning & Economic Development to the Council Executive – 16 December 2014

The Forth Invasive Non-Native Species Programme: Report by Head of Operational Services to the Council Executive – 07 February 2012

Restoration of the Bathgate Water: Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 12 February 2015

Restoration of the Bathgate Water: Report by Head of Operational Services to the Council Executive – 10 March 2015

Consultation on SEPA's Second River Catchment Management Plan for the Scotland River Basin District – Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 23 April 2015

SEPA consultation on developing the second river basin management plan for the Scotland River Basin District:
http://www.sepa.org.uk/water/river_basin_planning/scotland.aspx

Barriers to Fish Migration - River Almond – Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 04 June 2015

Barriers to Fish Migration – River Almond – Report by Head of Operational Services to the Council Executive – 30 June 2015

RiverLife: Almond & Avon Programme - Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 13 September 2016.

RiverLife: Almond & Avon Programme – Report by Head of Operational Services to the Council Executive – 11 October 2016

RiverLife: Almond & Avon – Novation & Procurement Exemption – Report by Head of Corporate Services to the Council Executive – 23 October 2018

RiverLife: Almond & Avon Programme – Report by Head of Operational Services to

the Environment Policy Development & Scrutiny Panel – 30 October 2018

RiverLife: Almond & Avon Programme – Report by Head of Operational Services to the Council Executive – 13 November 2018

RiverLife: Almond & Avon – Almond Barriers Project – Mid Calder Weir – Report by Head of Operational Services to the Environment Policy Development & Scrutiny Panel – 10 March 2020.

Appendices/Attachments: Appendix 1 - 'Option Appraisal of Fish Passes at Mid Calder Weir'

Contact Person: Graeme Hedger, Senior Professional Officer, 07774 479863, graeme.hedger@westlothian.gov.uk

CMT Member: Jim Jack, Head of Operational Services

Date of meeting: 24 March 2020

Option Appraisal of Fish Passes at Mid Calder Weir

West Lothian Council

January 2020

Quality information

Prepared by	Checked by	Verified by	Approved by
Nicklin Evans, Water Scientist Sara McBride, Senior Ecologist Mark Biesta, Senior Engineer Omar Sholi, Associate Director	Sally Homoncik, Senior Hydromorphologist Gill Wright, Principal Fisheries Scientist Omar Sholi	Andrew Brookes, Technical Director	Omar Sholi

Revision history

Revision	Revision date	Details	Authorized	Name	Position
1 Original	19-11-2019	Memo	OS	Omar Sholi	Associate
2	27-11-2019	Memo	OS	Omar Sholi	Associate
3	29-11-2019	Memo	OS	Omar Sholi	Associate
4	03-01-2020	Report	OS	Omar Sholi	Associate
5	10-01-2020	Report	OS	Omar Sholi	Associate

Prepared for:

West Lothian Council

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2. INTRODUCTION

2.1 Project Timeline

The Almond Barriers project is a catchment scale fish passage restoration project and a partnership between SEPA, the Forth Rivers Trust (formerly the River Forth Fisheries Trust) and relevant local authorities (West Lothian Council (WLC) and the City of Edinburgh Council). The project aims to re-establish fish migration through a >200 km length of the Almond catchment by improving fish passage at seven redundant weirs including Mid Calder weir. The project has involved a number of stages over a decade. These steps are discussed further in Table 2.1 below.

Table 2.1 River Almond Fish Passes Timeline

Stage	Date	Description
Conception and Cost Benefit	2010	The initial stage involved the River Forth Fisheries Trust undertaking a high level review of the effect of barriers at 25 structures along the river. SEPA reviewed this work in light of the River Basin Management Plan objectives for Scotland and the River Forth. There are multiple barriers on the main stem of the river, so improving fish passage at these barriers of the Almond would open up a large catchment (potentially >200km river and tributary length) to migratory fish. Around 12 RBMP waterbodies would improve in classification as part of the project (accessibility for fish would move from the current Poor Status, to Good Status). Value for money was considered during prioritisation to identify where WEF funding could apply (assessing the costs against the environmental gains).
Options Appraisal	2014 - 2015	High level options and constraints were assessed at the most significant barriers. This led to 8 barriers (Seafield, Kirkton, Howden Bridge, Mid Calder, Rugby Club, Limefield Falls, Dowie's Mill and Fair a Far weirs) being identified by SEPA for further action. More detailed option appraisal of at each of the 8 barriers was undertaken before a preferred option was established (two were identified at Mid Calder; weir removal or Larinier fish pass). Analyses were supported by survey works including topography/ bathymetry and structural surveys. Option appraisal was undertaken by Atkins while surveys were arranged by Mott MacDonald.
Outline or Detailed Design	2015-2016	Outline designs were completed by AECOM at 4 of the weirs (Kirkton, Rugby Club, Howden Bridge and Mid Calder weirs), with detailed designs prepared by JBA at 2 of the weirs (Dowie's Mill and Fair-a-Far weirs). The Mid Calder outline design project was delivered on behalf of the River and Fisheries Trust for Scotland, while SEPA and the FRT were part of the Project Steering Group. Following a detailed hydromorphological review the weir removal option was not considered appropriate (outlined further in Section 3.2) and was replaced by a partial rock ramp option. Through the outline design for Mid Calder, some differences between the two options were identified in terms of fish passage for different species and sizes, although it was concluded that both solutions should facilitate the passage of native species (notably salmonids). Subsequent design improvements, such as inclusion of a low flow channel through detailed design, would improve fish passage performance of a partial rock ramp. The conclusions also indicated that a partial rock ramp at Mid Calder Weir would provide a more natural solution (with it being designed to mimic the natural rapid/pool sequences of the River Almond), require less maintenance and would encourage less poaching[1] than the alternative Larinier solution.

[1] For the purposes of this report, poaching refers to the illegal taking of fish. This includes the taking of fish without a licence / permission, using illegal methods (e.g. nets) or outside of the allowable times of year. These acts are a wildlife crime under various clauses of the Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 (as amended). The offences range across a number areas which either directly or indirectly impact on the salmon and seat trout (all life stages) and are there to protect the populations of migratory and resident freshwater fish species.

Stage	Date	Description
Detailed design and construction	2017 - ongoing	Construction of the fish passes began in 2017 and is ongoing. Fish passage was delivered at Kirkton weir (single flight Larinier) and Fair a Far weir (renovated double back/ dual flight Larinier) in 2018. Fish passage was delivered at Howden Bridge weir (rock ramp) and Rugby Club weir (bypass channel).
Stakeholder events for Mid Calder	2019	WLC arranged two stakeholder consultation events (in East and Mid Calder) for local residents to learn more about the proposed partial rock ramp, which WLC intended to deliver to enable fish passage at Mid Calder weir. Locals were able to discuss the plans with representatives of FRT, AECOM, SEPA and WLC.
Detailed design of a partial rock ramp at Mid Calder	2019	AECOM was commissioned by WLC to further explore the design of a partial rock ramp. The initial draft results of this work were summarised in the "Mid Calder Rock Ramp – Initial Analyses Working Document", dated 23rd August 2019. This was released to the residents of Powie's Path and WLC and AECOM subsequently met with a number of the residents on the 19th September 2019. Some residents who live on the left-hand bank / north side of the river have raised concerns with the rock ramp and these were considered in the design note issued in November 2019.
Option (re-) appraisal at Mid Calder	2019 – 2020	This is the focus of this report and is described further in Section 2.2 below.

2.2 Option Re-Appraisal

Table 2.1 indicates the level of effort that has gone into developing a fish passage scheme at Mid Calder weir.

To enable a decision to be made regarding the way forward, WLC commissioned AECOM to review a shortlist of potentially viable options and compare the relative technical benefits and disbenefits of the options. The options considered within this appraisal are as follows:

- A partial rock ramp, as developed in recent work;
- A Larinier fish pass towards the middle of the river channel, as developed in 2016 to outline design level, but including further considerations as described in this report;
- A Larinier fish pass adjacent to the right-hand bank, similar to that installed at Fair-a-Far weir in Cramond, Edinburgh. A concept design was developed for this report to allow the option to be appraised; and
- A canalised fish pass along the right-hand bank. A concept design was developed for this report to allow the option to be appraised and informed by a similar fish pass at Hoghton Bottoms weir (Ribble Rivers Trust).

The purpose of this appraisal is to provide WLC with a technical review of the above fish pass options, considering a number of important differentiating factors.

It is important to note that AECOM was commissioned to provide an assessment of the options based on available information without undertaking significant additional design work. For example, designs for a partial rock ramp and central fish pass were relatively well developed, whereas designs for the canalised fish pass and bankside Larinier options can only be considered conceptual. It was therefore necessary to exercise judgement in the appraisal of some criteria. This is described in each of the sections of this report where relevant. The outputs of this assessment should therefore be considered comparative and high-level in nature.

2.3 Report Structure

This remainder of this document is as follows:

- Description of options being considered;
- Methodology (supporting analyses/ appraisal tools and options appraisal);
- Supporting analyses results;
- Option appraisal (Stages 1 to 3); and
- Option appraisal summary, conclusions and recommendations.

3. OPTIONS

3.1 Overview

The four different options are described in this section. Each of the options was developed and clarified based on AECOM's understanding of the site, previous analyses (e.g. results from the outline design), understanding of the types of fish passes themselves (e.g. hydraulic requirements, their passage efficacy at other sites) and technical literature (e.g. Environment Agency Fish Pass Manual, BFPP Supplement on Fishways, FAO Fish Passes).

3.2 Partial Rock Ramp with Low Flow Channel (Option 1)

3.2.1 *Design Summary*

The partial rock ramp and its design are presented in the "Mid Calder Partial Rock Ramp - Design Note" (produced by AECOM in November 2019). The design is currently at outline stage; a similar level of detail to the central Larinier fish pass (option 2). A full rock ramp option, which would normally be preferred over a partial rock ramp, has not been developed for the site. This is because, when the rock ramp option was first suggested for the site during AECOM's outline design work for RAFTS[2], one of the design requirements was to avoid substantive works in the left hand (secondary) channel due to land ownership constraints.

A schematic of the design is indicated in Figure 3.1 below (*note the final design would have a more natural appearance and not the regular forms shown*). The following features are expected to be included:

- Rock ramp constructed using similar materials as at Howden Bridge weir – a dense fill material, overlaid with boulders set in concrete. The aim would be to create a more natural appearance, however, where possible.
- A simple 1m wide low flow channel was included for this initial appraisal and in order to ensure fish passage would be achieved for the full flow range where passage is desired (i.e. Q95 to Q10 / low to high flows). Should this option be further developed, it is considered likely that the form of the rock ramp would be different to that at Howden Bridge to soften the visual appearance of the low flow channel, however AECOM has not developed the rock ramp option in such detail at this stage.
- The weir crest would be notched / adjusted to match the low flow channel. If feasible, it may be preferable to replace the weir crest with embedded rocks. The existing fish pass would be filled in.
- Measures would be included to reduce the risk of fish entering the side channel. This would include boulder placement to direct fish towards the main channel / right-hand bank and / or adjustments to the river bed (smoothing out) to make the secondary channel less attractive to fish.
- Three resting pools would be required to keep the length of each "rapid" section within the burst swimming capability of the fish. The resting pools would span the width of the channel to ensure energy dissipation is sufficient at elevated flows. As with the low flow channel the form of these could be altered from Howden to soften their visual appearance.

[2] AECOM (2016). West Lothian Weirs Outline Design

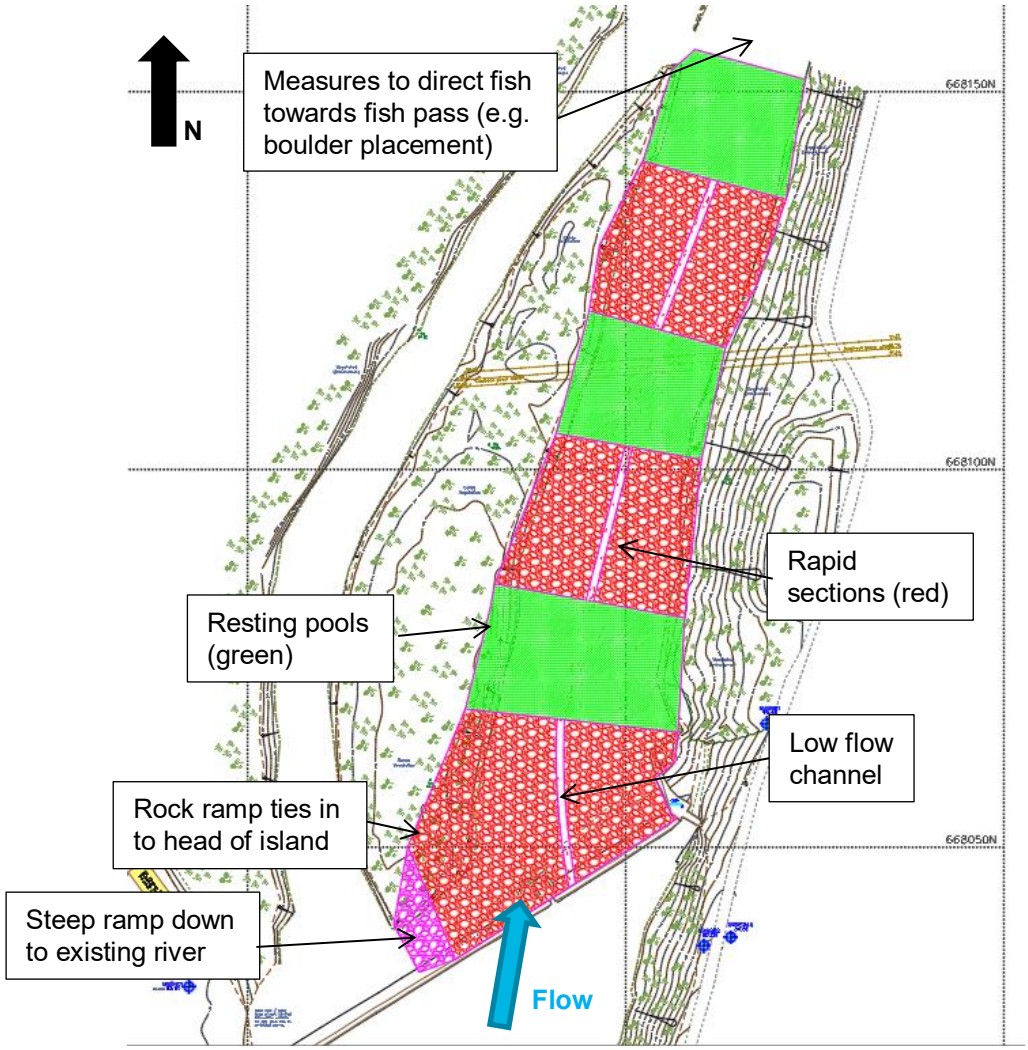

Figure 3.1 Indicative partial rock ramp with low flow channel

3.2.2 *In-built Mitigation*

The option described above includes mitigation for a range of issues that have been considered for the option. Designs for some of these have not been developed but it is assumed that these would be included should this option be further developed. Examples of such mitigation are as follows:

- Minimised low flow channel geometry to reduce impacts on distribution of flows (especially during low flows). This is to minimise ecological impacts and to help address landowner concerns;
- Rock ramp width at weir face set to maintain the same flow proportion as present during flood flows. This is to reduce the risk of scour in the left hand channel;
- Measures to reduce the likelihood of fish entering the secondary channel, as this would be a dead end for migrating fish. This would include maximising attraction flow on the fish pass by focussing flows, boulder placement to direct fish and reducing the attractiveness of the secondary channel by smoothing out the river bed; and
- Changes to the rock ramp form compared with Howden Bridge weir fish pass to soften / naturalise the appearance of the rock ramp and better distribute flows across the ramp.

3.2.3 *Further Development*

Further development of this option should consider the following (to highlight potential changes that could be made to the option presented):

- The exact low flow arrangement (invert level and geometry of low flow channel) to confirm the flow distribution at low flows. This will need to be a balance of maximising fish passage and attraction at low flows versus managing ecological impacts in the secondary channel and other concerns;

- Refinement of the rock ramp geometry to minimise impacts on flood flows; and
- Some measures may be required to protect the existing island and left channel from scour (refer to Section 5.2). If required, it is expected that this could be achieved using natural methods e.g. riprap placement, vegetation etc. The nature and extent of such measures would require to be determined should this option be progressed. These measures have not been included in this appraisal due to expected land ownership constraints.

3.3 Larinier Fish Pass (Central) (Option 2)

3.3.1 *Design Summary*

An outline design of a Larinier fish pass was produced by AECOM in 2016 and is shown in Figure 3.2 below. Results of this were presented in detail in the associated report[3]. The design is currently at outline stage, similar to the partial rock ramp.

Experiences from the Kirkton Weir Larinier fish pass are described in Appendix A.1. These are relevant to the appraisal of this option.

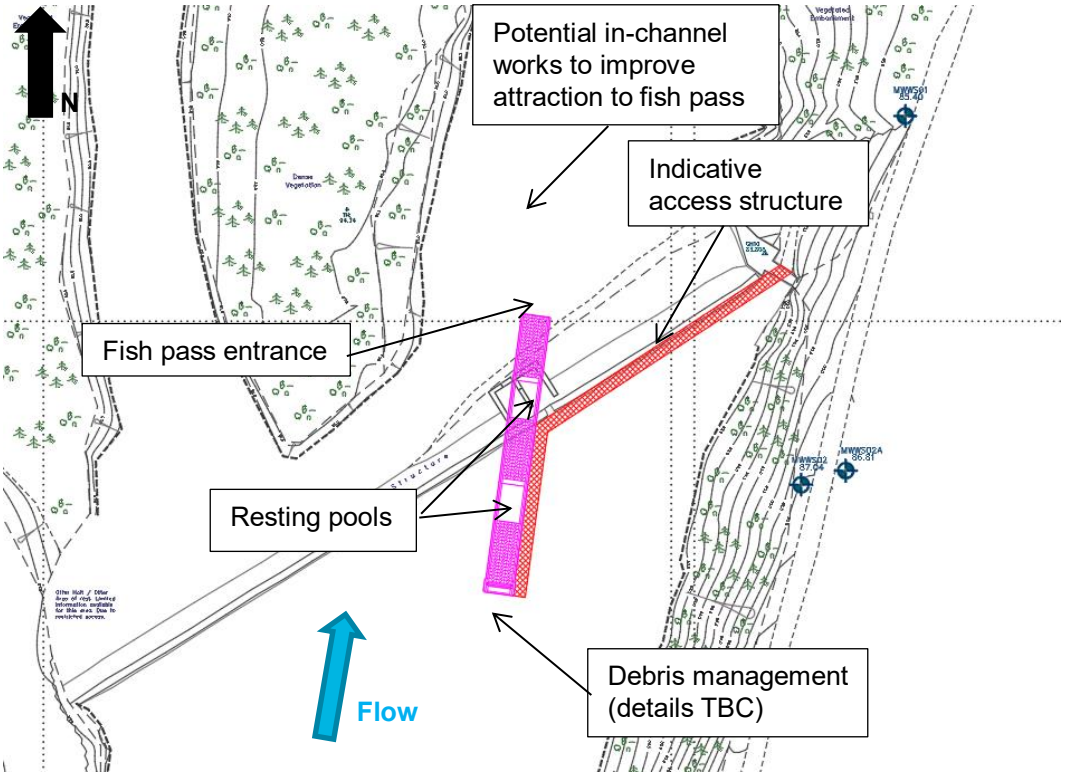

Figure 3.2 Proposed Larinier fish pass (central) location along with further details

Two locations were considered during the outline design for the location of the Larinier pass: against the right bank, or towards the middle of the right channel. The left channel was not further considered due to the limited flows in this channel and the potential for sediment build up on the inside of this bend in the river. It was agreed with the client and project group that the central location was preferred and developed to outline design. The primary driver for selecting the mid-channel location at the time was to minimise the risk of poaching. This would be aligned with natural attraction flow in the river and, due to the angle of the weir, the entrance would be further upstream than a fish pass next to the right bank. It was thought that the central location would also be away from both areas of sediment deposition on the left bank and the likely primary route for sediment transport near the right bank. Anecdotal evidence from local residents suggests that the primary route for floating debris is in the centre of the river, although it is not clear whether this is linked to the presence of the existing fish pass. Further consideration regarding debris would be required at detailed design.

Table 3.1 below summarises the final outline design parameters and comments on their selection.

[3] AECOM (2016) West Lothian Weirs Outline Design

Table 3.1 Summary of Larinier Fish Pass (Central)

Parameter	Value	Comment
Entrance	n/a	Downstream entrance to fish pass would be located at edge of concrete apron i.e. as far upstream as possible.
Gradient	15%	Gradient typically 10-15%. 15% was selected to minimise pass length
Baffle height	100 mm	Typical heights 100-150mm. A greater height would be used where there is significant variation in upstream head. This is not the case at the Mid Calder Weir and 100mm was therefore used as the less costly option.
Width	1.8 m	In terms of fish passage performance, there is not significant sensitivity to the width of the Larinier; the main difference is the proportion of flow that goes through the pass compared with over the weir. A width of 1.8m, selected at outline design, ensures a high proportion of flow goes through the pass whilst maintaining some flow over the weir even at very low flows (Q_{90}). To reduce the potential for adverse effects due to changes in the flow balance the Larinier fish pass could be narrowed to 1.2 m. A 1.2 m width was therefore used in the hydrological analyses (Section 5.1)
Invert level	200 mm below weir level	The invert level was selected to provide a balance between flow depth and velocity, in addition to maintaining flow over the weir at very low flows (Q_{90}). Narrowing the fish pass would maintain flow over the weir at even lower flows. The existing fish pass would be filled in.
Sidewall height	300 mm above Q_{10} water level	The sidewall level was set to reduce the risk of water spilling over the sides into the pass, which could otherwise disrupt flow patterns.
Resting pools	2 within the fish pass, with potential deepening of the river at the downstream entrance if required	Due to the length of the pass, a minimum of one resting pool would be required for the pass to be effective for most species. To improve passability, particularly for salmon parr and cyprinids, an additional resting pool was added to the design. The number of resting pools should be reviewed should this option be further developed.
Stop logs	n/a	A slot was added at the upstream end of the pass to allow the pass to be kept dry for maintenance works
Monitoring equipment	n/a	An additional slot was added downstream of the stop logs to allow monitoring equipment to be added without impeding the in-channel flow.
Debris deflector	n/a	Discussions were held with a Larinier baffle manufacturer (Aquatic Control Engineering) regarding blockages. It was noted that Larinier fish passes are generally less prone to blockage than other technical fish passes (EA Fish Pass Manual). For the purposes of this report, it was assumed that measures to deflect debris would be included. The detail of this would require confirmation should this option be progressed.
Covers (optional)	n/a	Covers would reduce the risk of people falling into the fish pass, debris entering the pass from above and poaching and predation. There would also be a risk of people being drawn into the fish pass by the strength of the current. The addition of covers would prevent safe escape in such an eventuality, so any covers would need to be combined with a security screen. The River Forth Fisheries Trust (now the Forth Rivers Trust) advised against the use of covers due to potential ongoing maintenance requirements. For the purposes of this report, it was assumed that no covers or screens would be fitted.
Eel passage	n/a	Two eel passes would be included – one at each river bank.
Maintenance access	n/a	Compared with Kirkton, a Larinier fish pass at Mid Calder would be less likely to trap debris due to the river channel being wider. With the proposed debris deflectors in place, the likelihood of needing maintenance intervention to remove debris should be much lower. Further consideration regarding maintenance access is required in discussion with WLC. For the purpose of this report, it was assumed that an access structure (gantry) would be required to ensure safe maintenance. This could be of a similar form to that at Kirkton weir.

3.3.2 *In-built Mitigation*

The option described above includes mitigation for a range of issues that have been considered for the option. Designs for some of these have not been developed but it is assumed that these would be included should this option be further developed. Examples of such mitigation are as follows:

- Separate eel, and potentially lamprey, passes near both the left and right river banks.
- Access structure to facilitate maintenance
- Measures to deflect debris away from the upstream end of the fish pass
- Larinier baffles would be stainless steel to reduce likelihood of them needing to be replaced during fish pass design life

3.3.3 *Further Development*

Further development of this option should consider the following (to highlight potential changes that could be made to the option presented):

- The exact low flow arrangement (fish pass width and / or inlet invert level) to confirm the flow distribution at low flows. This will need to be a balance of maximising attraction at low flows versus managing ecological impacts in the secondary channel and addressing landowner preferences.
- Whether the need for an access structure can be removed, or whether alternative access arrangements can be made such as a floating structure that can be rotated into position to reduce the visual impact.
- Whether there is a need for covers.
- Whether there is a need for in-channel works to facilitate fish finding the fish pass entrance, such as boulder placement.
- Alternative Larinier baffle materials to reduce construction costs.

3.4 Larinier Fish Pass (Right Bank) (Option 3)

3.4.1 *Design Summary*

The right bank location was re-introduced as an option for this option appraisal as it offers an alternative over the central option (refer to Section 3.3).

To allow appraisals to be carried out, an indicative concept design of a right bank Larinier fish pass was prepared. This arrangement would be similar in layout to that used at Fair-a-Far fish pass in Cramond, Edinburgh. There have been some post-construction issues at the Fair-a-Far Larinier fish pass; these are noted in Appendix A.2 along with commentary regarding potential solutions / whether the issues are relevant to Mid Calder.

Figure 3.3 below shows a sketch of a possible arrangement. There are several details that would require further consideration as noted in Table 3.2 below.

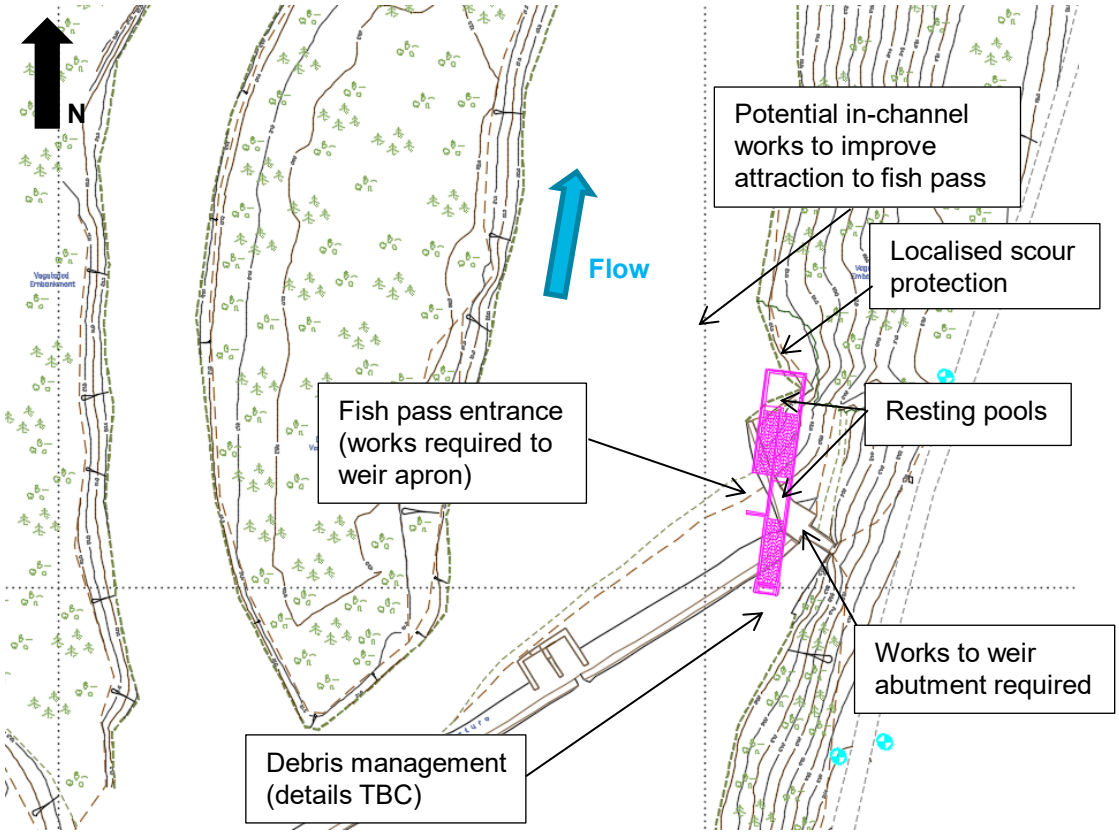

Figure 3.3 Potential right-bank Larinier fish pass arrangement

Table 3.2 below summarises the indicative design parameters and comments on their selection. A bankside location would address construction and maintenance challenges associated with the central location. Anecdotal evidence suggests that the floating debris load on the right river bank would be low, however consideration would be required as to whether the introduction of a fish pass would alter flow dynamics and the movement of debris. A river bank location is typically where fish would migrate to (EA Fish Pass Manual), although in the case of Mid Calder there is currently also strong attraction flow in the centre of the river. Fish are known to jump at the weir at this location (it is not known whether they also attempt to jump the weir at other locations).

Table 3.2 Summary of Larinier fish pass (Right Bank) option

Parameter	Value	Comment
Gradient	15%	As per central option
Baffle height	100 mm	As per central option
Width	1.2 m	Reduced to 1.2 m for reasons outlined in Table 3.1.
Invert level	200 mm below weir level	As per central option
Sidewall height	300 mm above Q_{10} water level	As per central option
Resting pools	2 in total	As per central option. In the case of this arrangement, having a longer upper flight is well-suited to the weir geometry.
Stop logs	n/a	As per central option
Monitoring equipment	n/a	As per central option
Debris deflectors	n/a	As per central option
Covers (optional)	n/a	As per central option. With a river bank location, it may be that covers offer a solution to the potentially increased risk of poaching. Further consideration would be required should this option be developed.
Channel works	n/a	Depending on the final arrangement, it may be that some in-channel works (e.g. boulder placement) would be included to maximise attraction of the fish pass. For the purposes of this report, it is assumed that such measures will be included.
Weir abutment	n/a	If the final arrangement is in the position of the current weir abutment, some works would be required to incorporate the fish pass into the weir and river bank.
Eel passage	n/a	Two eel passes would be included – one at each river bank.
Fencing	n/a	River bank waist-height fencing would be included for safety reasons.

3.4.2 *In-built Mitigation*

The option described above includes mitigation for a range of issues that have been considered for the option. Designs for some of these have not been developed but it is assumed that these would be included should this option be further developed. Examples of such mitigation are as follows:

- Separate eel, and potentially lamprey, passes near both the left and right river banks;
- Fencing to deter poachers;
- Measures to deflect debris away from the upstream end of the fish pass; and
- Larinier baffles would be stainless steel to reduce likelihood of them needing to be replaced during fish pass design life.
- Localised scour protection on the river bank downstream of the fish pass (e.g. riprap / geotextile / resilient vegetation)

3.4.3 *Further Development*

Further development of this option should consider the following (to highlight potential changes that could be made to the option presented):

- The exact low flow arrangement (fish pass width and / or inlet invert level) to confirm the flow distribution at low flows. This will need to be a balance of maximising attraction at low flows versus managing ecological impacts in the secondary channel and addressing landowner preferences;
- Whether there is a need for covers or other measures to reduce poaching;
- Whether there is a need for in-channel works to facilitate fish finding the fish pass entrance, such as boulder placement;
- Alternative Larinier baffle materials to reduce construction costs; and
- Details of works to the weir abutment – it may be necessary to move the fish pass so that it is adjacent to, rather than replacing, the existing weir abutment structure.

3.5 Canalised Fish Pass (Option 4)

3.5.1 *Design Summary*

The idea of a canalised fish pass option came about when trying to combine the benefits of a rock ramp (multi-species passage and natural appearance) with those of a Larinier fish pass (small footprint and impact on flow conditions). Such a structure was recently installed at Hoghton Bottoms Weir on the River Darwen in Lancashire – further described in Appendix A.3. Taking account of the findings of the review of the Hoghton Bottoms Weir site and available design guidance, an indicative concept design of a canalised fish pass at Mid Calder weir (see Figure 3.4) was developed and includes the following:

- Pass includes 3m wide ramps and pools (to provide an opportunity for fish to rest) of same length and slope as those designed for the partial rock ramp (Option 1) to maximise the likelihood of fish passage
- Rather than a formal low flow channel with notch, the whole channel would act as a low flow channel with a diversity of flow conditions provided using a variety of rock sizes.
- A notch would be cut into the weir (and the existing fish pass filled in) to provide fish passage at low flows. The notch would be over the full width of the fish pass to avoid the creation of a high-velocity jet of water at the top of the fish pass.
- A reinforced concrete retaining wall would divide the canalised fish pass from the rest of the river channel.
- To manage the risk of scour in the river channel resulting from water overtopping the dividing wall during a flood, some riprap may need to be installed in the river channel adjacent to the wall. For the purposes of this report, it is assumed that such works would be included, pending any investigation into scour risk should the option be further progressed.

- To manage the risk of fish missing the entrance to the fish pass, boulders would be placed in the river channel to direct fish towards the entrance. Nevertheless, it is expected to be difficult to manage this issue, particularly at high flows, due to the small proportion of overall flows within the fish pass.
- Similar to the Larinier fish passes, the narrow nature of the canalised fish pass means some debris management will be required. For the purposes of this report, it was assumed that debris deflectors would be included upstream.
- Whilst the canalised fish pass should provide passage for eels, an additional eel pass would be installed adjacent to the left bank to accommodate any eels that miss the fish pass entrance.

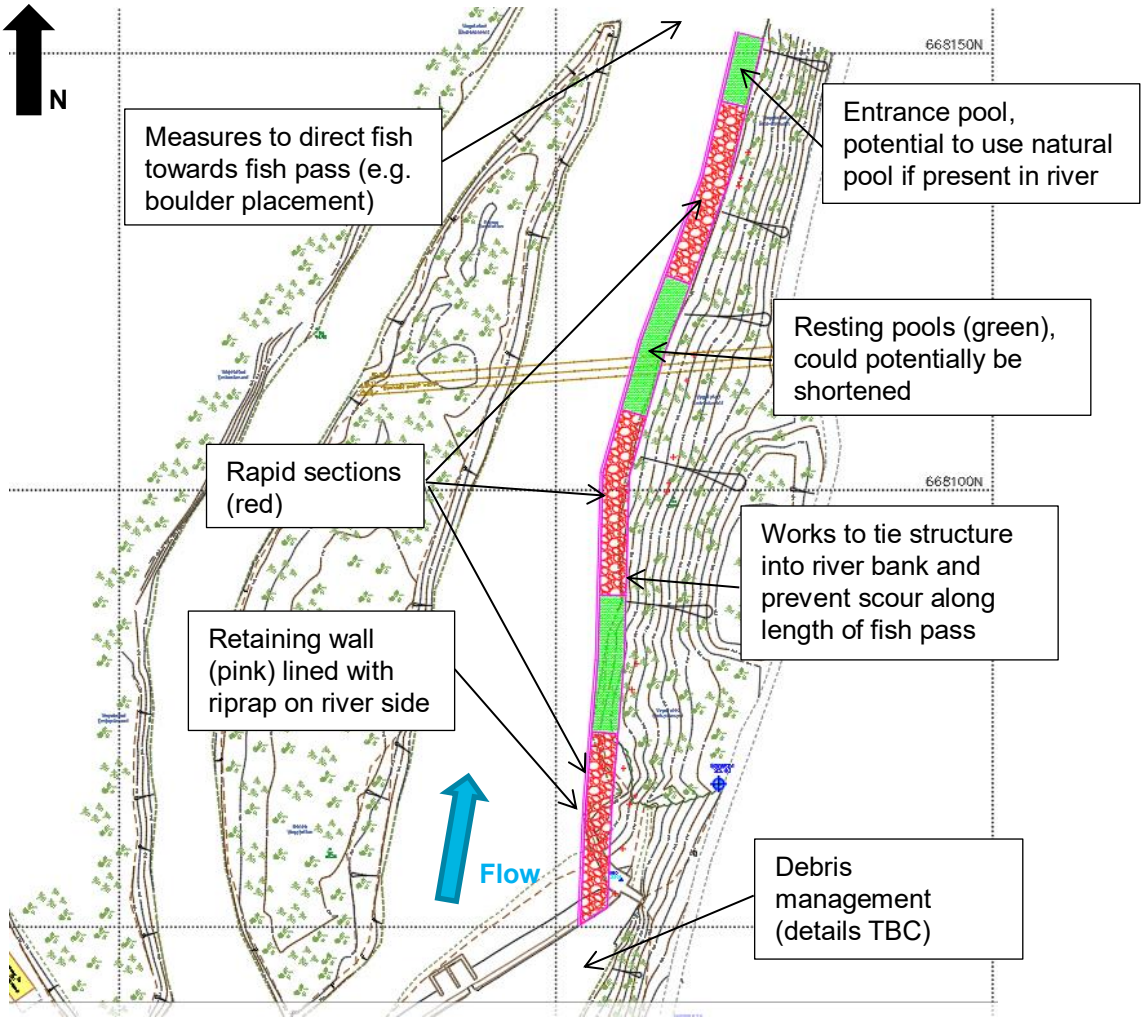

Figure 3.4 Plan of the Canalised Fish Pass initial design option

3.5.2 *In-built Mitigation*

The option described above includes mitigation for a range of issues that have been considered for the option. Designs for some of these have not been developed but it is assumed that these would be included should this option be further developed. Examples of such mitigation are as follows:

- Scour protection to river banks and channel to make the river resilient to changes resulting from the introduction of a rock ramp.
- Measures to reduce the likelihood of fish failing to enter the fish pass, as this would be a dead end for migrating fish. This would include maximising attraction flow on the fish pass by focussing flows, boulder placement to direct fish and reducing the attractiveness of the secondary channel by smoothing out the river bed.
- Eel and potentially lamprey passes at the left side of the weir.

3.5.3 *Further Development*

Further development of this option should consider the following (to highlight potential changes that could be made to the option presented):

- The exact low flow arrangement (invert level and geometry of entrance, including boulder placement within entrance) to confirm the flow distribution at low flows. This will need to be a balance of maximising fish passage and attraction at low flows versus managing ecological impacts in the secondary channel and addressing landowner preferences.
- The exact position of the structure at the upstream end i.e. how it interfaces with the existing weir abutment.
- Details of any required scour protection.

An alternative option involving a canalised rock ramp in a similar arrangement to Option 3 has not been considered. This would reduce the consequences of fish missing the entrance although collectively it is considered that such an option would unlikely not offer any significant benefits over Option 3 (while the passage type is unproven in the United Kingdom).

4. METHODOLOGY

4.1 Overview

The study has included two main aspects, discussed further below:

- Supporting analyses (to inform the option appraisal); and
- The option appraisal (split into stages).

4.2 Supporting Analyses and Appraisal Tools

4.2.1 *Appraisal Tools*

Two tools were developed during the initial analyses to reflect on the potential effect of the partial rock ramp on these matters. These were: a hydrological spreadsheet tool, to allow changes in flow balance to be appraised for varying design options, and a hydraulic model, which allows effects on flood risk and channel hydraulics/ hydromorphology to be appraised. The build of these is described further in the revised partial rock ramp design note (entitled “Mid Calder Partial Rock Ramp Design Note”). Both tools have been used as part of the appraisal of the four options presented here.

Current model results are considered appropriate to undertake a relative assessment between options although modelling should be iterated as the project advances, e.g. through detailed design. At this stage, the indicative modelling results should be treated with caution; further refinement was not considered to be warranted for this relative appraisal of options.

4.2.2 *Other Supporting Analyses*

In addition a number of other studies were undertaken to inform the option appraisal and overall decision making. This included collation of a cost evidence base to inform potential costs of the various options.

4.3 Option Appraisal

4.3.1 *Approach*

The appraisal of the options was carried out in three stages as set out below. The decision as to which criteria were covered under each stage was based on feedback from WLC, FRT, SEPA and local resident comments.

4.3.2 *Stage 1: Pass / Fail assessment*

Criteria

Stage 1 of the appraisal examined whether the options would result in any of the following:

- Increased flood risk to buildings that cannot be mitigated;
- Unacceptable health and safety risks that cannot be mitigated; and
- Unacceptable change to channel stability (e.g. channel planform could vary which could compromise structures or surrounding infrastructure).

Assessment

If an option resulted in a “yes” to any of the above it failed Stage 1. Options that passed progressed to Stage 2.

4.3.3 *Stage 2: Option Appraisal: Key Project Criteria*

Criteria

Options that progressed to Stage 2 were examined with regard to key project criteria (essentially that the scheme would result in successful fish passage while considering costs), these being:

- Fish passage: ability for multiple species to use the pass – is the depth and velocity of flooding suitable for the target species over the required range of flows?
- Fish passage: issues linked to multiple passage routes – how significant is the likelihood that fish do not find the entrance of the fish pass, and what are the consequences?
- Construction cost
- Maintenance burden (operational costs)

Assessment

The options were compared against one another to enable them to be ranked in terms of fish passage performance. Indicative construction costs and consideration of maintenance costs also allowed the options to be ranked in terms of lower cost to higher cost. Both cost and fish passage performance are key project criteria and collectively the fish passage performance and costs ranking and review were considered to determine which option would be more favourable at the end of Stage 2.

4.3.4 *Stage 3: Option Appraisal: Other Criteria*

Criteria

- Other ecological effects – do the options have any impacts (positive or negative) on ecology other than fish
- Flood risk to land and Powie's Path – do the options alter the risk of flooding?
- Hydromorphological effects – do the options alter the hydromorphology of the river?
- Land ownership – do the options require construction on land not owned by WLC?
- Aesthetic effects – do the options result in visual changes that may be attractive or unappealing?
- Buildability and risk – how easily can the fish passes be constructed and what are the risks that could increase construction costs?
- Health and safety – what are the safety considerations during construction, maintenance and operation?
- Risk of poaching – how does the risk of poaching compare between the options?

Assessment

Scoring for each topic was made as follows:

- +3 major beneficial effect
- +2 moderate beneficial effect
- +1 minor beneficial effect
- 0 neutral effect
- -1 minor adverse effect or complications
- -2 moderate adverse effect or complications
- -3 major adverse effect or significant complications

Particular criteria for each topic are discussed further during the appraisal of each topic, e.g. what would be considered as a significant benefit or disbenefit.

Cumulative scores for each option were not totalled as it is recognised that certain factors may be of greater importance than others (e.g. flood risk and fish passage performance would outweigh maintenance costs).

5. SUPPORTING ANALYSES

5.1 Hydrological Analyses

5.1.1 *Overview*

Any change to the river channel has the potential to affect flow patterns. In an ideal case, such changes would be minimal and inconsequential. The fish pass options being considered at Mid Calder have the potential to dry out sections of the weir and channel at times of low flow and affect the distribution of flows between the channels during all flows. This could have ecological, hydromorphological and aesthetic implications. From that perspective, it would therefore be beneficial to minimise effects on flow patterns. It is worth noting that changes in flows could have beneficial effects from a fish passage perspective e.g. increasing flow to improve attraction.

The hydrological baseline for the River Almond at Mid Calder weir is presented in the "Mid Calder Weir Partial Rock Ramp Design Report" (dated November 2019). Flow statistics presented included the Q_{95} (low flow), Q_{50} (moderate flow), and Q_{10} (high flow) for the River Almond at the Almondell gauging station (which lies approximately 500m downstream of Mid Calder Weir. Between these flows, fish passage would be expected to occur naturally. Channel changes, such as significant hydromorphological reworking or activity including erosion and subsequent deposition would generally not occur until larger flows (e.g. the 2 year flood or larger)[4].

5.1.2 *Scenarios*

The options were compared against one another using the hydrological analysis spreadsheet. The key differences between the options are the size of the notch in the weir. In all cases the existing fish pass would be filled in. Note that raising of the right-hand bank side for the rock ramp scenario was not undertaken for this assessment, refining the design slightly from that presented in the Design Note. The notch sizes assessed are as follows:

- Baseline: 0.13m deep x 0.5m wide;
- Option 1 – Partial rock ramp: 0.4m deep x 1m wide;
- Option 2 – Larinier fish pass towards middle of river: 0.2m deep x 1.2m wide (reduced from 1.8m shown in the outline design in anticipation of the requirement to reduce low flow impacts);
- Option 3 – Larinier fish pass adjacent to right river bank: 0.2m deep x 1.2m wide; and
- Option 4 – Canalised fish pass: 0.25m deep x 3m wide (modelled here as a clear opening; however in reality flow into the fish pass would be reduced by the presence of boulders).

5.1.3 *Hydrological Analysis Results*

Results of the analysis are presented in Figures 5.1 to 5.3.

[4] "Day-to-day" flows are typically described by the percentage of time that they are exceeded. E.g. a Q50 flow would be exceeded 50% of the time, or a total of 183 days in a typical year. Flood flows are the peak flows that typically occur less than once per year. They are typically described by their average frequency of occurrence. E.g. a 1 in 2 year flow would be exceeded on average once every two years, noting that it could be exceeded 10 years in a row and then not exceeded for the next 10 years. It is also referred to as having a 2 year return period or a 50% annual exceedance probability.

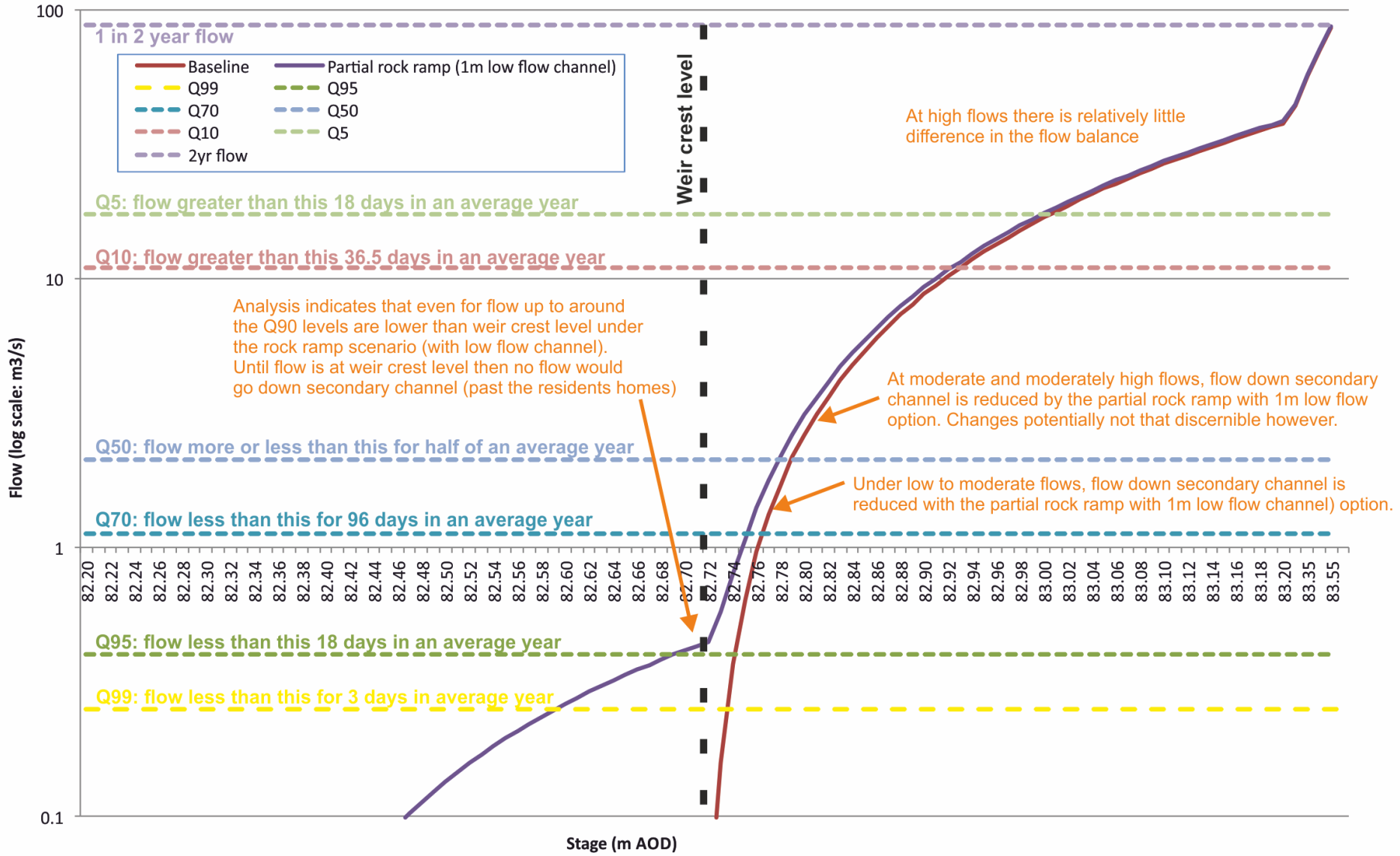

Figure 5.1 Comparison of hydrological effects of a partial rock ramp with 1 m low flow channel (Option 1) compared to the baseline

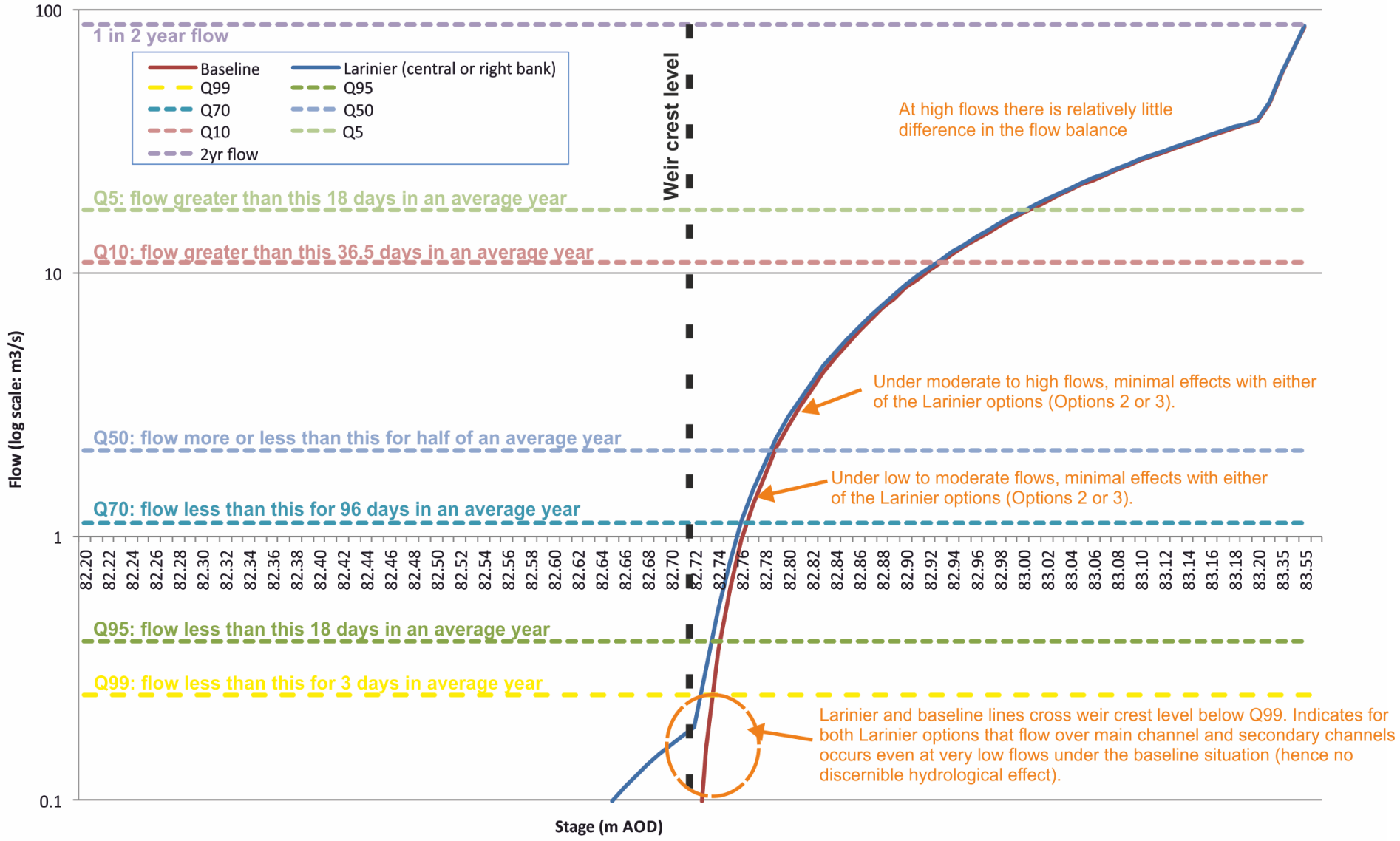

Figure 5.2 Comparison of hydrological effects of a Larinier central or right bank (Options 2 and 3) compared to the baseline

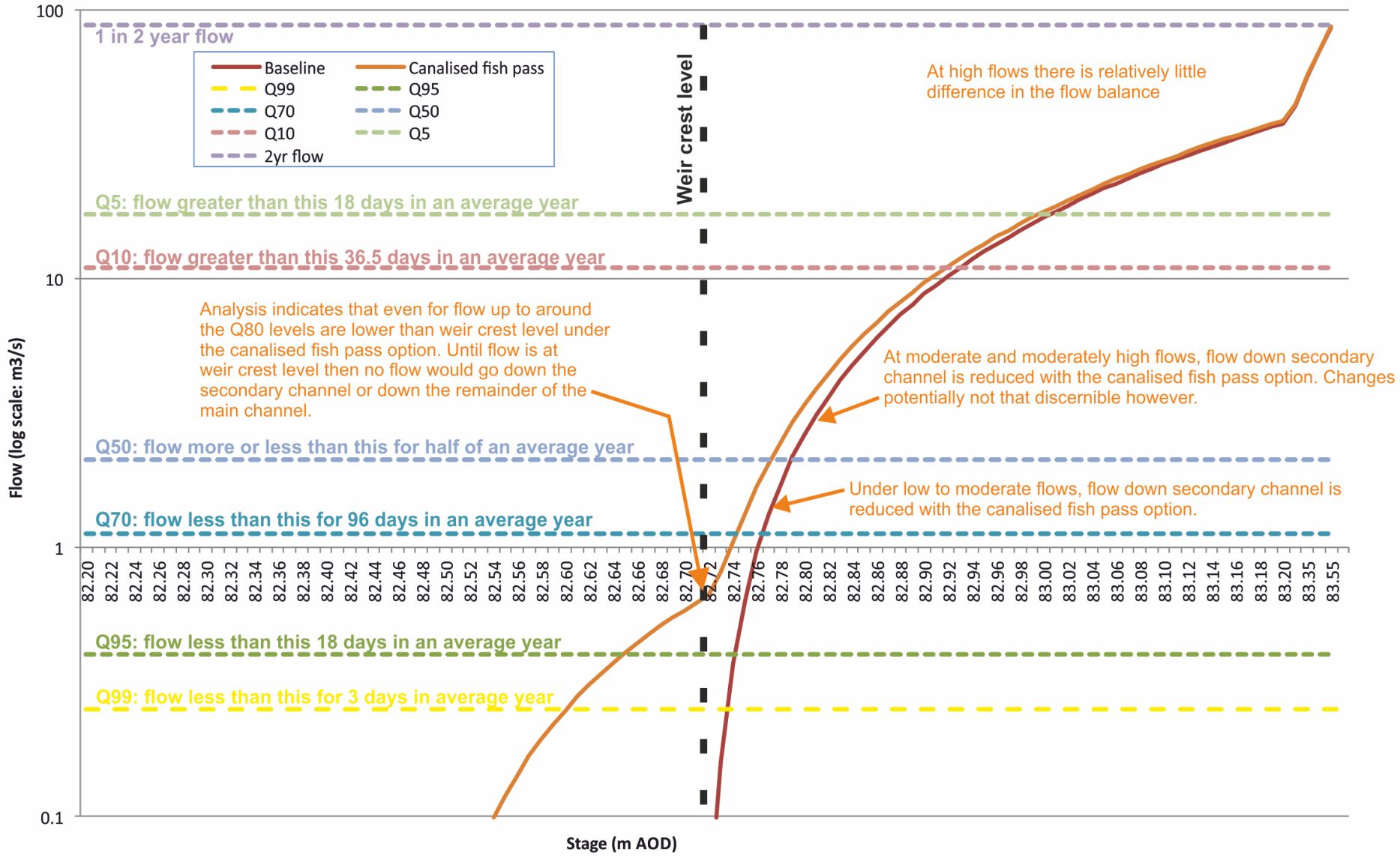

Figure 5.3 Comparison of hydrological effects of a canalised fish pass (Option 4) compared to the baseline

The analysis indicated that the **canalised fish pass** would result in the weir and secondary channel being dry for around 20% of an average year (approximately 73 days). This is supported by the results of the hydraulic modelling of the low flows. This would be a significant change and would have visual and ecological effects (refer to Sections 5.4, 8.1 and 8.6). With increased flow the effect of the canalised fish pass would diminish although significant hydrological changes, in terms of the flow balance, would be expected up to moderate flows.

The analysis indicated that the **partial rock ramp** would result in flow only going down the low flow channel and neither the surface of the rock ramp or secondary channel for around 10% of an average year (a total of approximately 36 days). This is supported by the results of the hydraulic modelling of low flows. Again, although not as extreme as the canalised fish pass, this would be a significant change. It would also have a significant visual effect when viewed from the river bank on the residents' side, with any visual effect on the other side being subject to the design of the structure. It would also have ecological effects (discussed further in section 0). Again, with increased flow the effect of the partial rock ramp would diminish although significant hydrological changes, in terms of the flow balance, would be expected up to moderate flows.

The outline design of the **Larinier fish pass (central)** was based on a 1.8m wide structure. Even the 1.2m wide structure assessed in this section would require more flow than is currently going down the existing (ineffective) fish pass. However, thanalysis has indicated that the difference would be minimal and probably imperceptible. For the baseline and both of the **Larinier fish pass (central or right bank)** options, flow would be going down the secondary channel (and remainder of the main channel) at the Q_{99} (flow is less than this for a total of 3 days a year on average). As such there would be no perceptible visual changes and no significant ecological effects as a result of drying out of the river channel.

A summary of the typical number of days in a year that would have no flow over the weir under the baseline and fish pass options is presented in Table 5.1 below. Climate change can potentially aggravate low flows and these are projected to increase in frequency in Central Scotland, including the Almond catchment[5]. The number of days where there may be no flow over the weir is likely to increase as a result of climate change.

Table 5.1 Summary of Scenarios examined through the Hydrological Analyses

Option	Baseline	1. Partial Rock Ramp	2. and 3. Larinier (central or right bank)	3. Canalised Fish Pass
Total time (days) in a typical year during which there would be no flow over the weir	>3	36	>3	73

Based on the above, *from a flow balance and hydrological perspective*, with subsequent hydromorphological, visual and ecological effects, the Larinier options would result in the least effect particularly at times of low flow. It should be noted that the options have been developed to differing levels of detail and the results of this analysis may be subject to change. For example, the canalised channel could be narrowed to take less water, making flow patterns more similar to the partial rock ramp option shown; however, it would still result in a large portion of the river being dried out for extended periods of time. It is therefore considered unlikely that the overall conclusions would be affected by such changes.

At high flows the effects of any of the fish pass options on flow balance would not be discernible.

[5] https://www.sepa.org.uk/media/159070/climate_change_water_scarcity.pdf Accessed 27 November 2019

5.2 Hydraulic Review Including Flood Risk and Hydromorphology

5.2.1 *Overview*

Hydraulic modelling of the canalised fish pass and partial rock ramp options was undertaken and compared to a baseline situation. Hydraulic modelling of the **Larinier options** is not required as the structure is unlikely to have an effect on flood risk or lead to significant changes in channel hydraulics due to its small size. Results of the modelling are presented in Figures 5.4 and 5.5.

It should be noted that the assessment has accounted for a 20% increase in extreme flood flows (for the 200 year event) as a result of climate change. More recent research guidance has become available since a general 20% uplift was recommended, and this should be taken into account as part of any further work.

5.2.2 *Flood Flows*

Flood Risk

No changes in channel hydraulics / flooding extents are apparent between the baseline and **canalised fish pass option**. This is due to the fact that the canalised rock ramp only takes up a very small proportion of the overall channel. The following discussion therefore only concerns the **partial rock ramp option**.

The model indicates that during a flood under baseline conditions, water would initially start to flow out of bank along the left bank near the weir and in the wooded area on the left bank downstream of the weir. As flows increase, water would spill out of channel further upstream of the weir, inundating the ground between Powie's Path and the river, as well as Powie's path itself. Water would flow down the path before discharging back to the river downstream of the weir. Flooding along the right bank of the river channel is limited by steep slopes.

The partial rock ramp option would involve the raising of a significant reach of the right hand channel. This would have a consequential effect on channel capacity downstream of the weir, meaning more water would flow onto the island and into the secondary channel. With no major modifications to the weir crest itself, the impacts upstream would be limited and caused only by the backwater effect of raised water levels on the rock ramp. Table 5.2 shows the effects on water levels in several key areas.

Table 5.2 Impacts on water levels and flood risk at key locations

Location	Baseline flood frequency	Impact of partial rock ramp	Comment
Upstream of weir, including land between Powie's Path and river channel	Between 2 and 100 year return period	Negligible (all return periods modelled)	Backwater effect of rock ramp is limited to immediate vicinity of weir
Weir crest	n/a	Up to around 30mm	Minor effect associate with backwater effect from rock ramp
Downstream of the weir, wooded area between Powie's Path and river (left bank)	Localised flooding below 2 year return period	~0.5m (2 year return period) ~0.2m (100 year return period) ~0.08m (200 year return period with climate change uplift)	Effects rapidly diminish with increasing flow; impact on flood extent is limited due to steep nature of banks. Impact is not considered to be significant
Island	Between 2 and 100 year return period	Flood frequency increased to more frequent than the 2 year return period.	Change in flood risk is considered inconsequential for example in relation to tree growth, notwithstanding potential effects on hydromorphology (discussed further below). The change in flood frequency may be perceptible to the local residents who may have never seen the island fully overtopped.

Location	Baseline flood frequency	Impact of partial rock ramp	Comment
Powie's Path beside House Number 4	Mostly between 100 year and 200 year return period with climate change uplift	Flood frequency increased to around the 100 year return period	More frequent and more extensive flooding of Powie's Path at the property. This is likely to be inconsequential in terms of access as the road would be flooded further upstream anyway (where the frequency of flooding would be unaffected by the fish pass). Parking is on higher ground and would not be affected.
Properties	Unknown	Unknown, but impact on flood levels likely to be less than 0.08m	The modelling did not include flood events extreme enough to assess risks to the properties. Floor levels are also not available and cannot be accurately determined from available DTM data. It appears that properties are at least 1m higher than the largest flood included in this analysis, suggesting that there is likely to be little or no risk of flooding. Since impacts of the partial rock ramp on water levels diminish with increasing flows, it may be that there is no effect on flood risk at the properties. In any case it is unlikely to affect the risk categorisation. Should the partial rock ramp be further developed, the impact on more extreme flows should be assessed.

Hydromorphology

The boulder/cobble pool-rapid main channel flows through a more confined valley setting with steep channel margins and valley sides. This morphology suggests a high energy watercourse and further evidence of this and the river's potential to change its form is provided by the historic bank collapse on the right bank close to the wastewater treatment works.

Naturally functioning pool-rapid sequences like those seen on the river through Livingston are interesting in terms of their form and function in relation to this project. The rapid areas are naturally composed of a framework of boulders with a matrix infill of finer cobble/gravel/sand. The boulder framework is often a legacy of former flood regimes, more aligned with post glacial conditions on the river. These have stabilised to act as near permanent hydraulic controls on the watercourse. The extreme roughness created by the boulder matrix allows sediment to become trapped in interstitial spaces where they are effectively protected from transport by the sheltering effects of the boulders. Spacing between rapids is often quite variable as a result of this legacy formation and intervening pools can be fully flushed of delivered sediment during floods or can accumulate active transport barforms which are temporarily stored before being remobilised and replaced with new material from upstream during floods. Hence both the rapids and pools form an inherently stable gross morphologic template over which contemporary bedload transport processes operate.

Upstream of the barrier the watercourse hydromorphology has been significantly modified by the impounding effect of the weir and a run/glide in-channel habitat has replaced a pool-rapid system for around 250 – 300m upstream. Unusually for the river there has also been significant sediment accumulation behind the weir, particularly on the right bank where a stable bar feature has developed exhibiting a varied set of habitats consistent with a prograding sedimentary feature. The sediment is coming principally from the right bank tributary. The feature has developed in line with the elevated water level behind the weir and would be severely eroded were the weir to be removed. The relationship between the bar vegetation communities and the water table / river level would also be fundamentally altered impacting on their functionality. On the left bank the narrow valley bottom slopes more gently into the channel and this area has been utilised by householders along Powie's Path forming a well maintained grassed margin.

Essentially at the site there is a low risk of change, in normal to large floods as the channel section below the weir is circa twice the expected natural width so that stream powers over a range of flows would be reduced.

No changes in planform are predicted as a result of any of the schemes and no knock on effects on infrastructure or other structures are predicted.

Potential effects of the options could include the following:

1. Redirection of flow onto a bank or specific part of the bed causing erosion (and potentially the invoking the need for erosion protection);
2. Reduction of capacity by the works, causing erosion elsewhere in the section;

3. Increased channel roughness (potentially slowing particular flows); and
4. Inducing instability of bare earth banks by concentrating flows through secondary channels etc.

Through a review of the different options and flood flow modelling results, it is considered that a **partial rock ramp** map result in the first, second and fourth effects. Potential effects may be reduced through mitigation though the feasibility of such mitigation is questionable given potential constraints. The appraisal has assumed that no mitigation is carried out.

A **canalised fish pass** may result in the second and fourth effects, however due to the narrow size of the fish pass the effects are likely to be limited. Mitigation to reduce the effect of these has been included given that it is located on WLC owned land.

No hydromorphological effects are associated with the **central Larinier fish pass** option. The **right bank Larinier fish pass** option may result in the first effect were water to cascade out of the downstream resting pool onto the river bank. The option assessed here includes mitigation to address this.

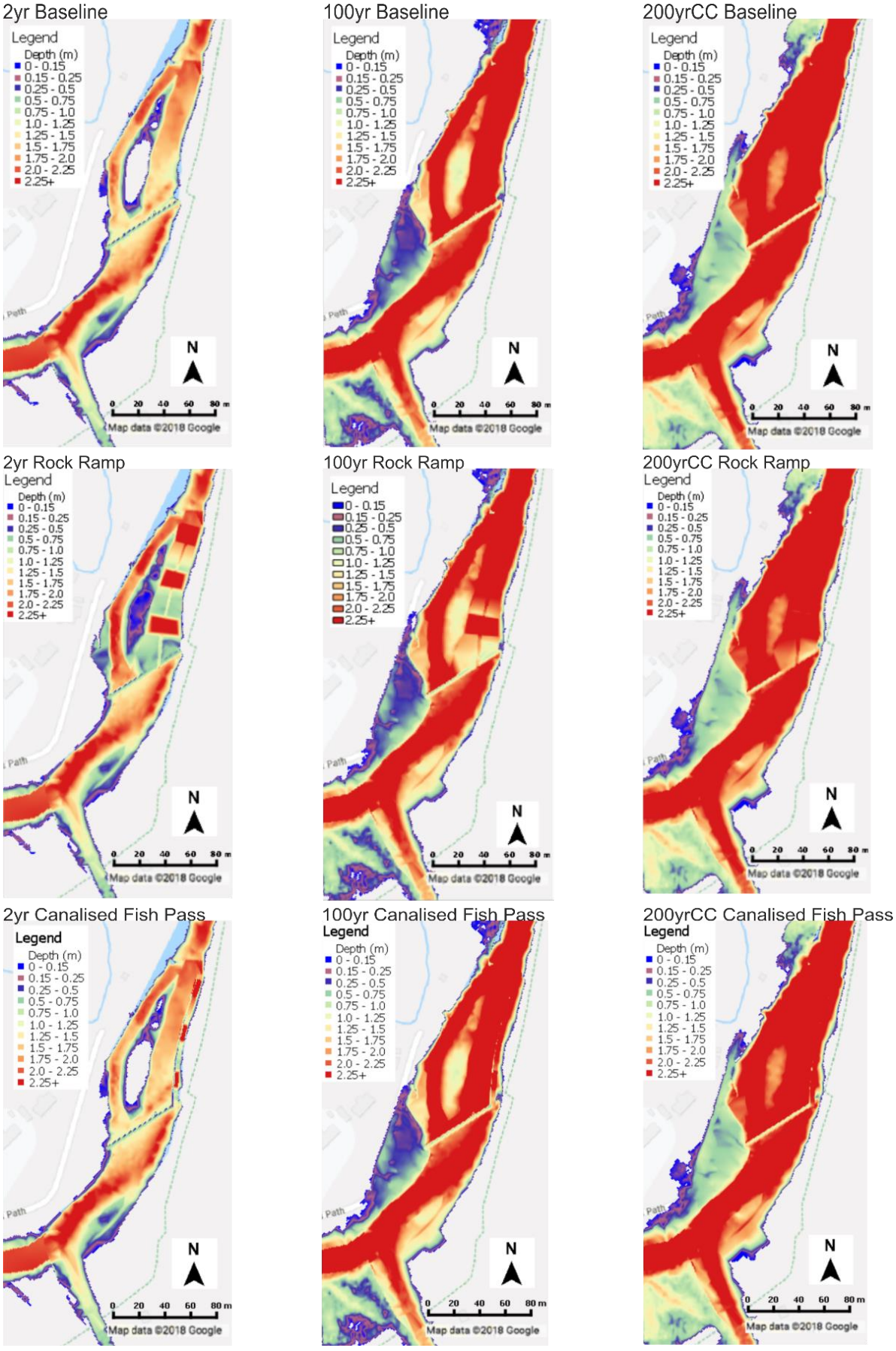

Figure 5.4 Flooding depth for the 2 year, 100 year and 200 year (plus climate change) return period events

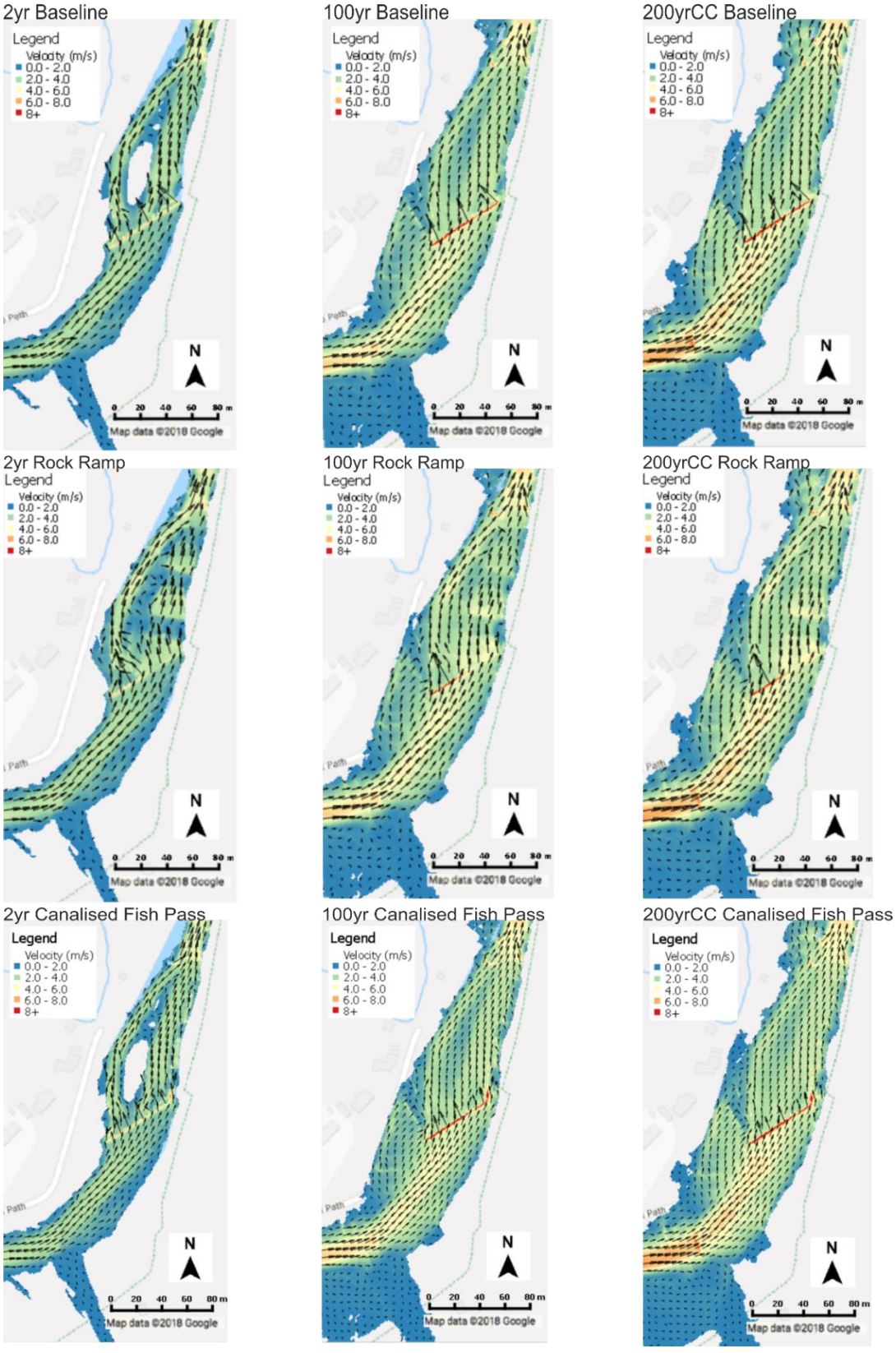

Figure 5.5 Flow velocities for the 2 year, 100 year and 200 year (plus climate change) return period events

5.2.3 *Typical Flows*

The impact of the options on the distribution of more day-to-day flows is described in section 5.1.3, and this is confirmed by the hydraulic model results shown in Figures 5.6 and 5.7. The figures clearly show the significant impacts of the partial and canalised rock ramp options on the lowest of flows.

The model resolution is not ideal for assessing small-scale depths and velocities (e.g. between individual boulders and within the flow channel), however the results do provide some evidence to support assessment of fish passage. This is further discussed in Section 5.3.

The effect of the options on typical flows can also have aesthetic and ecological impacts; these are further discussed in Sections 5.4 and 8.1 for Other Ecology and Section 8.5 for aesthetics.

5.2.4 *Hydraulic Modelling Results Summary*

The hydraulic analysis showed that flood risk is not affected by the **canalised fish pass** or **Larinie**r options due to the minor changes in channel geometry. The effect of the **partial rock ramp** is likely to be small and inconsequential in terms of flood risk to land. Flooding to properties would only occur for flows in excess of those modelled, and the impact on property flood risk could therefore not be assessed. Based on the information available at this time, it is considered likely that there would be little or no risk of property flooding whether a rock ramp is there or not. The possibility of some impact (for example changing the flooding probability from 1 in 1,500 years to 1 in 1,400 years[6]) cannot be ruled out, however. Additional modelling would be required to confirm flood risk impacts should a partial rock ramp be further considered.

Potential hydromorphological effects are likely to occur under flood flows. A **partial rock ramp** could result in a redirection of flow onto a bank or specific part of the bed causing erosion (and potentially the invoking the need for erosion protection), reduction of capacity by the works (causing erosion elsewhere in the section) and inducing instability of bare earth banks by concentrating flows through secondary channels. Potential effects may be reduced through mitigation though the feasibility of such mitigation is questionable given potential land ownership constraints. The appraisal has assumed that no mitigation is carried out.

A **canalised fish pass** may result in reduction of capacity by the works (causing erosion elsewhere in the section) and inducing instability of bare earth banks by concentrating flows through secondary channels. Mitigation to reduce the effect of these is more likely given that it is located on WLC owned land.

No hydromorphological effects are associated with the **central Larinier fish pass** option. The **right bank Larinier fish pass** option may result in redirection of flow onto a bank or specific part of the bed causing erosion. The erosion protection included in this option would mitigate this.

[6] Numbers are hypothetical to demonstrate the point being made

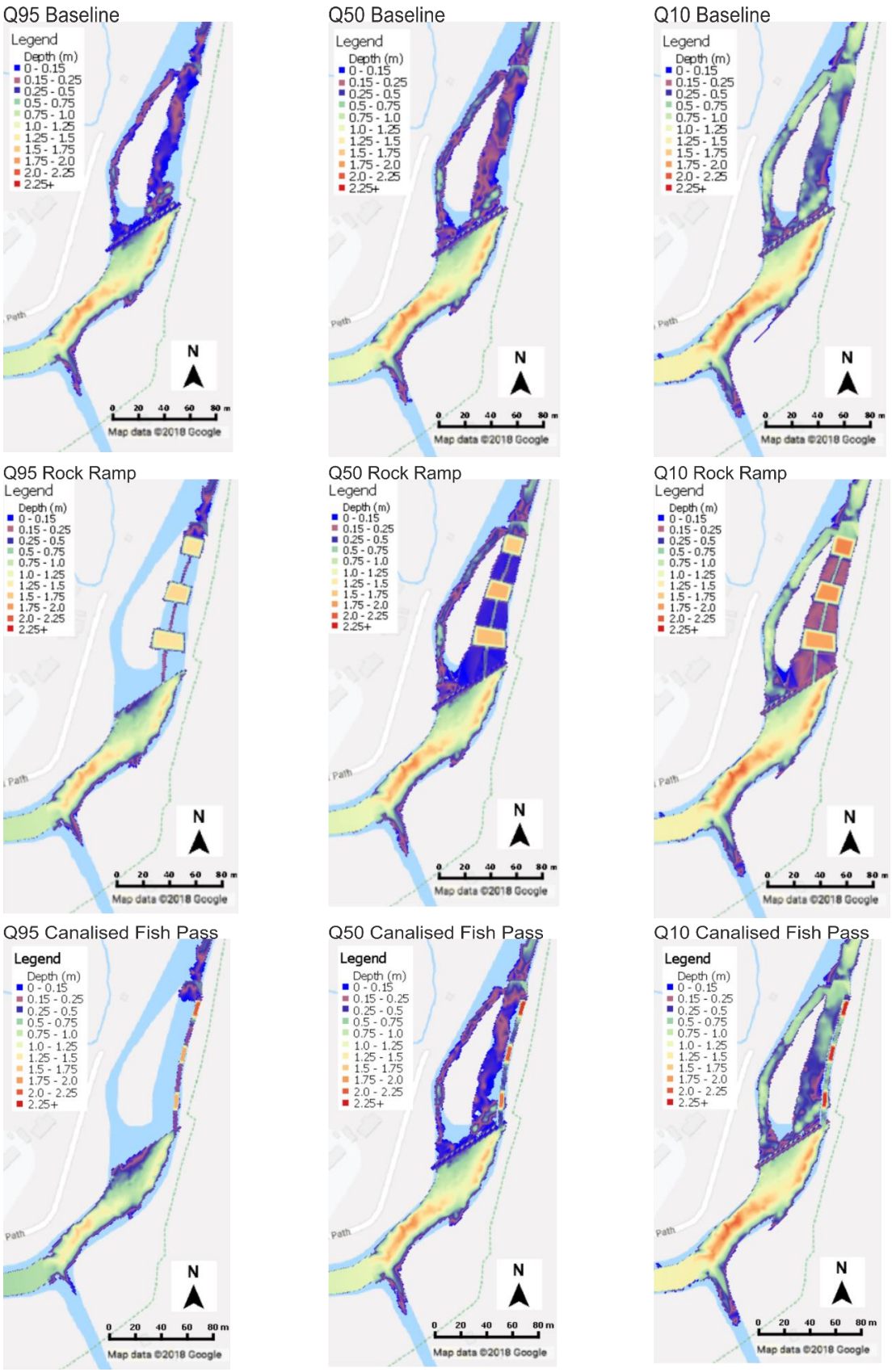

Figure 5.6 Modelled water depth for Q_{95} (low), Q_{50} (moderate) and Q_{10} (high) flows

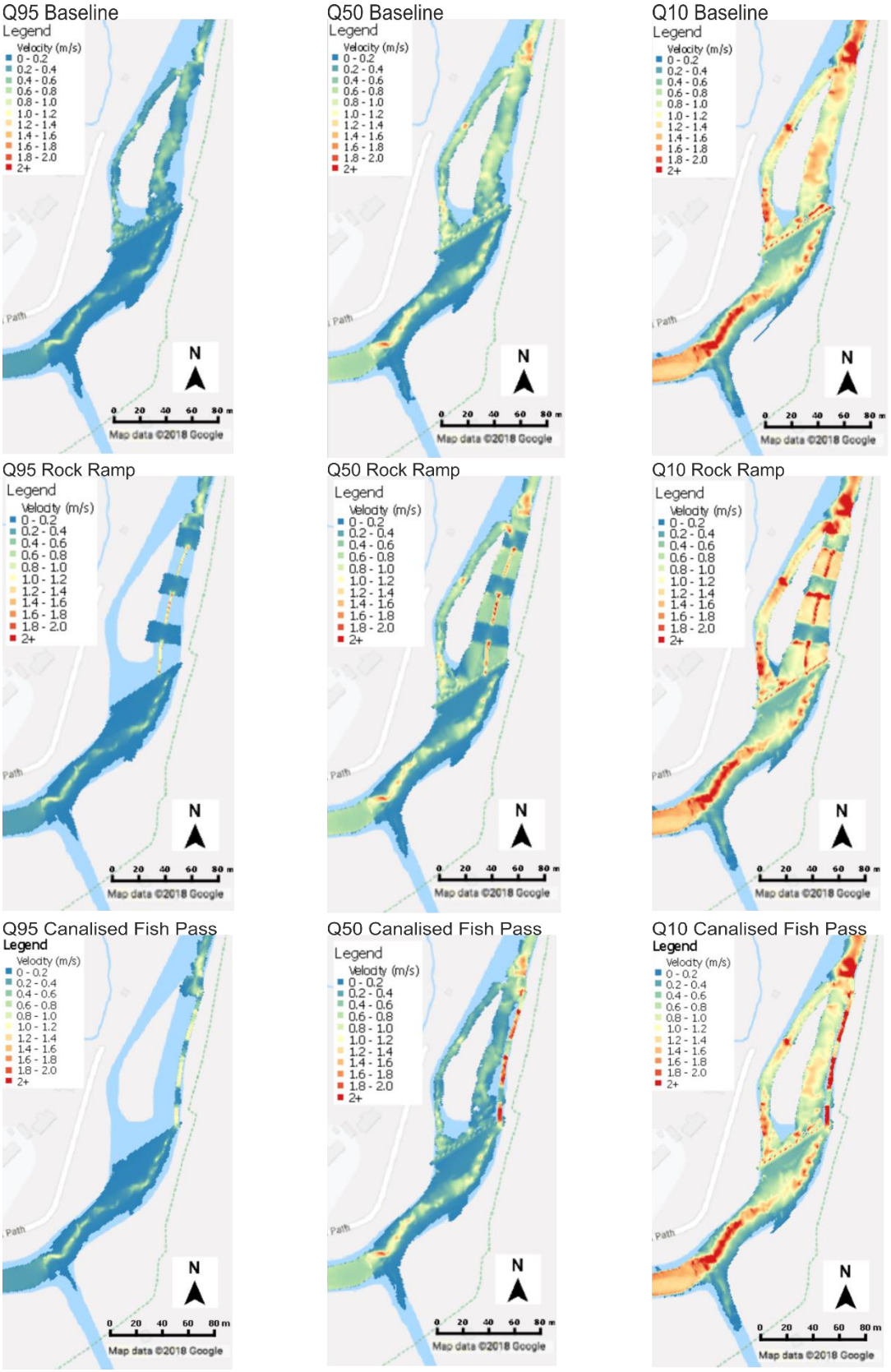

Figure 5.7 Modelled water velocities for Q_{95} (low), Q_{50} (moderate) and Q_{10} (high) flows

5.3 Fish Passage

5.3.1 *Overview and Passage Requirements*

The following hierarchy of fish passage solutions is typically applied when considering options (EA Fish Pass Manual):

- Removal or partial removal;
- Other modifications or easements;
- Inclusion of a nature-like fish pass; or
- Inclusion of a formal / technical fish pass.

It is recognised that site specific characteristics may mean that certain options higher up this hierarchy are not favoured at a particular site. Weir removal was not considered appropriate during outline design as undesirable hydromorphological changes could result[7].

The fish passage requirements are set out in detail in AECOM's 2016 report *West Lothian Weirs Outline Design.* In summary, a fish pass should meet the following requirements:

- Free passage for target species: salmon, brown / sea trout, lamprey and eel; other species being of secondary concern;
- Depth and velocities to be appropriate for fish passage for the range of flows when fish would be expected to migrate (generally Q90 – Q10);
- Strong attraction flow so that fish migrating upstream are able to find the fish pass; and
- Minimise the potential impact of fish missing the fish pass entrance.

5.3.2 *Review*

Larinier Fish Pass

The attractiveness/ functionality of a Larinier fish pass was generally assessed as high for most species during the outline design phase (specifically for a central pass through results apply to a right bank pass too). In-built mitigation such an elver pass would ensure that passage for poorer swimmers would also be achieved.

Performance of the other two options was assessed using results from the hydraulic modelling, presented in Figures 5.6 and 5.7 in Section 5.2.3.

Partial Rock Ramp

Water depths (Figure 5.6) in the low flow channel and/or over the rock ramp at higher flows appear to sufficient for multiple species passage, indicating that the simulated rock ramp and low flow channel design would deliver fish passage at the site. This should be confirmed through further investigation, however, e.g. 1D or more detailed 2D hydraulic modelling or hydraulic calculations if the design is progressed to detailed design. Water velocities under the flow range in which passage is desired (Figure 5.7) suggest that passage would be possible through the low flow channel or rock ramp structure. Refinement of the design could attempt to further encourage passage / attract fish up the main (partial rock ramp) channel, since any fish that went up the secondary channel would encounter a significant obstacle to passage.

A partial rock ramp would carry a greater proportion of overall flow, thus making it more attractive than the other options (noting that the change in flow balance may have other adverse effects).

Rock ramps would generally offer benefits to a wider range of aquatic life when compared with technical fish passes, which tend to be more species-specific. Although this is not the primary objective of the proposed fish pass, this may factor into decision-making.

Canalised Fish Pass

Water depths (Figure 5.6) in the canalised fish pass appear sufficient for multiple species passage at low and moderate flows though potentially excessive at high flows. Passage could potentially be improved through

[7] AECOM (2016) West Lothian Weirs Outline Design

detailed design though there would be less variability in flow routes compared to the rock ramp. Passage should again be confirmed through further investigations however, e.g. 1d hydraulic modelling or hydraulic calculations if the design is progressed to detailed design. Water velocities under the flow range in which passage is desired (Figure 5.7) suggest that passage would be possible through the canalised fish pass at low and moderate flows although may be too high under high flows.

The canalised rock ramp would only carry a slightly greater flow than the Larinier option, and the greater number of competing attracting flows, particularly at high flows, would limit attractiveness. A key drawback of a partial or canalised rock ramp is the location of the entrance relative to the weir; any fish missing the entrance would find themselves going up the “wrong” channel and meeting a dead end. This could cause significant delay to migration with fish having to either wait for elevated flows, when the weir may be passable to the strongest swimmers, or return some 100-150m downstream to find the entrance.

Although refinement of the design could further encourage passage / attract fish up the canalised fish pass, the much larger section of river without a fish pass is likely to limit the success of this option. A doubled-back arrangement, with the fish pass entrance closer to the weir would significantly reduce this risk.

5.3.3 *Results*

The modelling of more day-to-day flows supported the conclusions presented in Section 5.1.3 regarding flow distribution, and indicated that the partial rock ramp and canalised fish pass options should permit fish passage for a wide range of flows (a Larinier being able to deliver fish passage was confirmed during the outline design).

From the attraction perspective, none of the options are ideal but in each case mitigation options exist. For example behavioural deterrents could be introduced at the secondary channel for a partial rock ramp (noting that this would have construction and operational costs) or modifications to the lower end of the island area could be made to reduce the attractiveness of the channel for migrating fish. Similarly, the Larinier fish pass could be widened or lowered to take more flow. Whilst the attraction flow of a Larinier fish pass may be weaker (unless it is widened to take more flow), the consequences of fish initially missing the entrance are significantly reduced.

On balance of the above discussion, it is considered that a partial rock ramp would offer the greatest fish passage benefits. This option is not without drawbacks, but mitigation options exist to reduce the effects. Either Larinier fish passage option would overall provide the second best option for fish passage and in some respects are more favourable to the partial rock ramp. The canalised fish pass option would provide a means for successful fish passage though it has significant drawbacks associated with it, when compared to any of the other 3 options.

5.4 Other Ecology

A new fish pass could result in other ecological effects during construction (e.g. linked with pollution events) as well as during operation of the pass (e.g. loss of in channel habitat). Adverse impacts as a result of construction phase pollution events may negatively affect aquatic and terrestrial habitats; such impacts are similar for all options and would be subject to strict mitigation requirements (see below and that should be included within a Construction Environment Management Plan). This mitigation is considered as “in-built” for the purpose of this appraisal.

Similarly, the appraisal does not include for residual effects following implementation of mitigation, compensation and enhancement. Required mitigation may include planting of woodland, scrub and grassland habitat and / or enhancement of existing retained habitat, invasive non-native species management and strict biosecurity, survey and licencing for protected species and measures to make the secondary channel less attractive to aquatic fauna should it be affected by low flows. Such mitigation is considered feasible, and, given the likely importance of ecological features present, residual effects on all ecological features identified are likely to be negligible. Furthermore, beneficial effects are highly likely (for all Options), attributed to the improvement in fish passage beyond Mid Calder Weir which will benefit fish species directly and potentially other species such as macroinvertebrates and otters (as a result of increased prey resource).

Our appraisal has considered the effect of the four options on other ecology, with regard to aspects such as the following:

- Changes in the flow balance (as outlined in Section 5.1);

- Loss of or provision of new in channel habitat; and
- Loss of trees with bat roost potential.

A brief ecological review of the three options discussed in this note are provided below. For full ecological baseline and assessment of impacts of a partial rock-ramp type option, see Mid Calder Weir Ecological Impact Assessment[8]. Non-rock ramp options were not proposed at the time of writing the Ecological Impact Assessment (EclA), so were not discussed in this report.

Construction of a partial rock ramp with low flow channel (Option 1) will require removal of strips of mature, native, but floristically unremarkable broadleaf woodland along the south bank of the river channel and south bank of the island. This may include loss of one tree with low bat roost suitability and is likely to disturb invasive non-native plants species (including Japanese knotweed and giant hogweed) with associated risks of them spreading. As the footprint of this option is the largest, construction may result in disturbance to an otter holt on the north bank of the river. It would also result in the greatest loss of aquatic habitat, although large areas of comparable habitat will remain in the near area and new in channel habitat will form as the scheme matures. During operation, Option 1 would result in no flow over the surface of the rock ramp or secondary channel for around 10% of an average year (approximately 36 days), this may result in impacts on fish and macroinvertebrate populations (which based on FRT data / biological monitoring working party (BMWP) values are likely to be good). In a worst-case scenario (and in the absence of mitigation, see below), such impacts may include entrapment of aquatic fauna within unsuitable habitat (e.g. dry areas / poorly oxygenated pools). Operational effects on the in-channel downstream island are also possible including erosion and / or increased saturation affecting vegetation composition / tree roots.

A Larinier fish pass (central/ Option 2 or right bank/ Option 3) would have the smallest footprint of the three options. Construction of either would therefore result in the least terrestrial and aquatic habitat loss, least potential disturbance to invasive non-native species and probably no impacts on trees with bat roost suitability / otter refuges. Flows over the weir / secondary channel would essentially be as baseline during operation of the fish pass, so no effects on the aquatic fauna in the secondary channel would be anticipated. Option 2 is considered to score slightly better overall as it would not result in permanent loss of bankside habitat or trees with bat roost potential.

Construction of a canalised fish pass (Option 4) would require woodland removal on the south bank of the river, but no impact to habitats on the island. This slightly reduces the risk of disturbance to invasive non-native species. The tree with bat roost suitability may require to be removed, but disturbance impacts on otter refuges are less likely. Aquatic habitat will be impacted upon (less than Option 1, but more that Options 2 or 3 3) although as noted above large areas of comparable aquatic habitat will remain. Option 3 would result in the weir and secondary channel being dry during operation of the pass for around 20% of an average year (approximately 73 days). Impacts of this are similar to those noted for Option 1 (potential impacts on aquatic fauna), but of increased magnitude as it may occur twice as often and affect a greater area.

Access tracks, a temporary compound and river access ramps to facilitate construction of the fish pass will be located on the south bank of the river for all Options. Depending on the final positioning of this infrastructure, possible construction impacts may include loss of neutral grassland with scrub, loss of regenerating native woodland, impacts (included disturbance / loss) on trees with bat roost suitability, and impacts upon terrestrial habitat used by great crested newt. Operational effects associated with construction infrastructure are not anticipated and affected habitat will be fully remediated following construction.

5.5 Design and Construction Costs

5.5.1 *Overview*

Comparative cost estimates are required to allow appraisal of the options. Without developed designs for the canalised fish pass and bankside Larinier options, it was not considered appropriate to attempt to estimate quantities of materials etc. for these options. Although more detailed cost estimates for the partial rock ramp and central Larinier options were prepared at outline design stage (by AECOM in 2016), designs have been

[8] AECOM (2019) Mid Calder Weir Ecological Impact Assessment. Dated 29th August 2019 (note this contains sensitive information on badger sett locations and should only be released to the public if such information has been redacted).

further developed and additional information is available from the construction of fish passes at Kirkton and Howden Bridge weirs. The original cost estimates are therefore no longer considered to be valid.

There has been wide variance in the value of tender returns to date for projects forming part of the Almond Barriers project. This highlights the level of uncertainty in cost-estimating within the river environment, even when significant information is available to tenderers.

When compared to the larger construction costs there is not expected to be a significant difference between the options in costs for the following items. Although these items are included in this assessment, the primary focus is on comparison of the capital costs for the physical works.

- Design;
- Supervision including fish rescue (noting that more extended projects would necessitate prolonged efforts);
- Allowances for risk and optimism bias; and
- Access and enabling works are also likely to cost similar between options. Access at Mid Calder could extend over quite a large length of track from the B7015, 400m to the south of the weir, which may result in access costs substantially higher than at Kirkton or Howden where access was relatively straightforward.

Client costs and regulator / permitting costs were excluded.

5.5.2 *Evidence Base*

The following information (Table 5.3) was gathered to inform potential costs for the different fish passage options. All costs are approximate and exclude design unless stated otherwise. As they are a relatively rare concept, no information is readily available for canalised rock ramps.

Table 5.3 Collated cost evidence to inform potential construction costs

Site	Cost	Source	Description
Rock ramps			
Mid Calder	Total including design and supervision: £360,000	AECOM estimated cost based on input from small contractor (costs may be higher for large framework contractors) and on outline design	Cost based on 2016 outline design – partial rock ramp without low flow channel. Access from treatment works.
Howden	Design: £130,000 Supervision: £100,000 Construction: £700,000	As-built costs on AECOM project.	Similar weir height to Mid Calder but rock ramp constructed across full width of channel necessitating more materials and longer time on site. Work completed over the autumn and winter and so extended due to cold weather and reduced working days. Overall costs much higher than outline design estimate with input from small contractor.
Retford	Construction*: £260,000	As-built costs[9]	Weir height was originally ~1m and watercourse is much smaller than Howden; access reportedly difficult
Larinier fish pass (central location, single flight)			
Kirkton	Design: £100,000 Construction: £170,000	As-built costs on AECOM project	Single flight fish pass set back in the weir, 2 baffles wide
Larinier fish pass (central location, multiple flight)			
Darley Abbey	Construction*: £320,000	As-built costs[10]	2-flight fish pass, 4 baffles wide. Installed downstream of weir
Mid Calder	Total including design and supervision: £390,000	AECOM estimated cost based on input from small contractor – costs may be higher for large framework contractors	Cost based on 2016 outline design. Access from treatment works.

[9] https://restorerivers.eu/wiki/index.php?title=Case_study%3ARiver_Idle_Hallcroft_(Tiln)_Weir_Fish_Pass Accessed 29 November 2019
[10] https://restorerivers.eu/wiki/index.php?title=Case_study%3ADarley_Abbey_Fish_Pass_Project Accessed 29 November 2019

Site	Cost	Source	Description
Larinier (bankside, single flight)			
Burley Mill and St Ann's Mill Weirs	Design and Construction: £400,000	As-built costs[11]	Two single-flight fish passes set back in the weir, 4 baffles wide. Construction by small contractor.
Hadfield	Construction**: £350,000	As-built costs[12]	Single flight set back in weir, 4 baffles wide
Larinier (bankside, multiple flight)			
Borrow-ash	Construction*: £650,000	As-built costs[13]	Very large structure (3 flights) including sheet piling. Installed around weir abutment
Seven-acres	Total costs £500,000	As-built costs	Two flight structure within an enclosed structure including screens
Fair-a-Far	Design: Unknown/ £50,000 estimated Supervision: £70,000 Construction: £520,000	As-built costs on AECOM project	Two flight fish pass downstream of weir, 2 baffles wide. Challenging access and weather conditions

** It is not clear whether the cost includes construction supervision and design costs*

*** Reported costs vary by £50,000*

5.5.3 *Construction Cost Estimates*

Cost estimates for the four options are provided below. Costs include design, construction and supervision and assume works are undertaken in the summer when there is least risk of disruptions to construction.

Partial Rock Ramp

Without undertaking a new detailed cost assessment, it is considered that the previous estimate carried out at outline design stage is likely to be on the low side. Experience at Howden fish pass suggested the cost estimates made at outline design were too low. Subsequent work has also shown a need for a low flow channel, and a new access track over a length of approx. 500m would be required. It is considered reasonable to increase the estimate to £600,000 - £800,000. Costs may be higher if there are access issues or if more expensive materials are used in the build (e.g. for rock ramp to appear more natural).

Larinier Fish Pass (Central)

The Kirkton weir project came in at approximately the fee estimated during outline design. As such, there may be an argument that the design and build costs at Mid Calder for a Larinier based on the outline design may remain valid. However, construction access complications and other additional requirements such as maintenance access, may mean that the final costs are higher. As such a range between £400,000-£600,000 is considered appropriate.

Larinier Fish Pass (Right Bank)

A double and back Larinier fish pass on the right bank, such as that at Fair a Far, may be more straightforward to construct than a central pass but may require works to the weir abutment. Overall costs for this arrangement are likely to be of a similar order to the central Larinier arrangement.

Canalised Fish Pass

Without an available design or examples of costs for similar projects, it is difficult to provide a reliable estimate. The costs discussed under the rock ramp heading above provide some indication of likely costs. Although the physical works would be reduced in footprint, there would be a need for a long (most likely reinforced concrete) structure. This would essentially make this an option a combination of a rock ramp and a Larinier fish pass. A bankside location would improve access for construction and reduce the challenge of

[11] https://restorerivers.eu/wiki/index.php?title=Case_study%3AKirkstall_Valley_Weir_Fish_Passes_Project Accessed 29 November 2019
[12] https://restorerivers.eu/wiki/index.php?title=Case_study%3AHadfield_Weir_Fish_Pass Accessed 29 November 2019
[13] https://restorerivers.eu/wiki/index.php?title=Case_study%3ABorrowash_fish_pass Accessed 29 November 2019

working in the river relative to the other options as they stand. It is considered that costs for a canalised fish pass would be of a similar order of magnitude as the Larinier options i.e. £400,000 - £600,000.

5.6 Maintenance Considerations

5.6.1 *Overview*

Maintenance would be carried out in the following circumstances:

- Debris affecting flood risk;
- Debris affecting fish passage;
- Debris being unsightly / receipt of public complaints;
- Adjustment to fish pass e.g. to respond to river adjustment; and
- General maintenance e.g. replacement of worn components.

Most fish passes would require some degree of maintenance; all would require regular inspection. Weir removal would provide the lowest maintenance costs, provided the river achieves a stable form following weir removal. All other options would involve a structure with an on-going maintenance liability.

Given its age, some deterioration of the weir potentially requiring works should be expected with the design life of any fish pass. A partial rock ramp would offer some support to a substantial portion of the weir; the other options would not provide any such benefits.

5.6.2 *Debris Accumulation*

For the purposes of this section, debris is deemed to include items such as shopping trolleys, branches and river sediments. Consideration of debris accumulation was based on three factors: the likelihood of trapping debris, the likelihood for trapped debris to impede fish passage and the ease with which debris could be cleared. The actual maintenance burden would very much depend on the amount and nature of debris arriving at the structure, and there is little information available with which to make a robust assessment. Anecdotal evidence from residents at Powie's Path suggests very little debris would arrive on the right bank. It is unclear, however, whether that observation would change if a fish pass were installed near the right bank, drawing more water to that location. If very little debris is arriving at the weir, then the propensity of the different arrangements to trap debris and the difficulty of clearing it becomes an irrelevance.

Experience at Kirkton has shown that the size of debris being washed down the river is greater than had been expected. The decision to place the fish pass in the channel rather than at the side has created an in-channel obstacle where debris can collect and ultimately resulted in WLC installing an access structure. The structure has also led to debris, such as trees, being impinged onto it. Maintenance of the Larinier fish pass is now easier and safer. WLC has advised that each maintenance visit costs around £500 and since April 2018, £2,000 has been spent (equivalent to £1.3k/ year).

At Fair-a-Far weir, there has been a large volume of sediment transported by the river. It is understood that the fish pass appears able to transport this downstream, although it is not clear if the resting pool has been checked. No maintenance costs have been obtained.

At Howden, the primary debris requiring removal has been shopping trolleys, which collect outside of the low flow channel following floods. The prevalence of shopping trolleys is likely to be linked to the town-centre location of the fish pass. At Mid Calder, it is likely that debris would be more natural, but shopping trolleys were seen on the island during site visits. Tree branches etc. are understood to be occasionally deposited at Howden but then flushed onwards. Again, these are not gathering in the low flow channels. It is possible that the high-energy environment of the low flow channels is preventing debris building up there. It should be noted that this pass was only completed in March 2019. No information on WLC maintenance costs has been obtained.

Compared with the partial rock ramp option, a Larinier fish pass or canalised fish pass at Mid Calder would have an increased **likelihood of trapping debris** due to the raised walls. Furthermore, the relatively small size of the resting pools for the Larinier and canalised options makes these less resilient to debris accumulation. The proposed Larinier and canalised options set out in this report include measures to reduce the risk of debris becoming trapped, thereby reducing the maintenance burden. River sediments are likely to

be transported through each of the fish passes, although some sediment management may occasionally be required (sediment management does not appear to have been required at any of the fish passes installed along the River Almond to date, although the eel pass at Fair-a-Far is experiencing some accumulation).

Since all options include a low flow channel, it is considered equally likely that, if debris became trapped, **fish passage** would be affected. The partial rock ramp may provide alternative routes available for fish passage over the rest of the ramp and would therefore offer a degree of resilience.

In terms of **access**, the Larinier option adjacent to the river bank and the canalised fish pass would be most easily reached for maintenance. Whilst the central Larinier option would have an access structure, its position in the centre of the river would still make it more challenging to clear debris. Whilst the low flow channel of a partial rock ramp could be relatively easily reach by walking across the ramp, the uneven surface would make this less safe.

On balance, it is considered that a partial rock ramp would involve the least onerous debris management, followed by bankside options and finally the central Larinier fish pass. The difference between the options is considered relatively small, however.

5.6.3 *Adjustment to Fish Pass*

Rivers are dynamic environments and any change to flow conditions can cause changes to the river. For example, the channel or river banks can be scoured due to increasing flow velocities or depths, or sediments can be deposited where flows are slowed down. Such issues are considered during the design process of a fish pass and where necessary mitigation measures can be implemented to address these. Nevertheless, there remains a possibility that the river channel does not respond in a way that is expected. Where such changes affect fish passage, flood risk or structural integrity (of fish pass or other infrastructure) there could be a need for works to address the issue.

Since a Larinier fish pass or canalised fish pass would not significantly change flow dynamics in the river, the likelihood of works being needed is low. A partial rock ramp would result in a more substantial change to flows and the likelihood of works being needed at some point in the future is therefore greater. The actual likelihood would depend on the detail of the final design and the resilience of the river to change, and it is difficult to say what might be a suitable cost allowance might be to cover such eventualities. The aim would typically be to design a fish pass where there is no need for future intervention at all. Some localised adjustment may occur with the partial rock ramp in place, and potential mitigation measures have not been included in this appraisal.

5.6.4 *Structural Maintenance / Asset Replacement*

The main fish pass structure would normally be designed with a long design life of the order of 100 years. Elements such as (reinforced) concrete, natural stone and vegetation would typically require no works over their design life. Parts of the works that have a shorter design life may require replacement – this could include eel pass tiles, Larinier tiles, gabions and rock bags / mattresses. A Larinier fish pass would have more components likely to require replacement when compared with a partial rock ramp or canalised fish pass. Design choices can influence the need for such works e.g. the selection of more robust materials could reduce or in some cases even remove the need for maintenance.

The lifespan of Larinier baffles would depend on the material choice and the forces of the river (impact from debris and abrasion). Provided that abrasion is low, stainless steel baffles could potentially last for 100 years and therefore require no replacement (fixings may require replacement / tightening – a relatively small job); HDPE baffles are more likely to need replacing due to damage or wear, perhaps every 20 years or so. The same would apply to any eel pass(es) installed. There is uncertainty regarding future works; the weir itself may require significant works at some point in the next 100 years, and fish passage technology may have significantly advanced, not to mention any changes to hydrology.

Assuming the stainless steel Larinier tiles are used, it is considered that the main works required over the lifetime of the Larinier or canalised options would be replacement eel passes. Since these are relatively low-cost measures, this is not considered to be a significant consideration. Maintenance for a partial rock ramp could involve replacing missing stones, clearing vegetation growth (where problematic) or patching up concrete (e.g. if damaged by root action).

5.6.5 *Maintenance Summary*

Without more detailed studies, it is difficult to provide a conclusive assessment of likely maintenance requirements for each of the options. The analysis presented here are the typical considerations made when designing fish passes. The debris load at Mid Calder weir is not considered to be unusually high and there is little to choose between the options in terms of routine structural maintenance / asset replacement, although there is some uncertainty as to how the river would respond to a partial rock ramp. Maintenance is unlikely to be a deciding factor between the options. It is noted that WLC may have a greater interest in the maintenance burden than might typically be the case, as specific funding is available for capital costs but not maintenance. Rather than providing a choice between options, however, it is suggested that maintenance should guide the design of the option, as each option can be designed to minimise the maintenance burden.

5.7 Health and Safety

None of the options are without risks; the key risks in terms of forming a fish pass at Mid Calder weir are considered to be flood risk, which is linked to the position of the fish pass and the proportion of the river to be isolated for construction, and making amendments to the existing weir structure. There are many more considerations (similar to those set out in the buildability section), however these are considered to be the key differentiating issues. In terms of construction risks, options would therefore rank as follows, starting with the lowest risk.

1. Right bank Larinier fish pass (Option 3) – construction near river bank without removing large portions of the fish pass
2. Canalised fish pass (Option 4) – construction near river bank but over long extent, without removing large portions of the weir
3. Partial rock ramp (Option 1) – construction across full width of main channel but downstream of weir and requires isolation of majority of right-hand channel
4. Central Larinier fish pass (Option 2) – requires isolation of majority of right-hand channel and involves significant amendments to weir structure

Notwithstanding that, it is considered that any of the options could be constructed with risks managed to an acceptable level.

During operation, the key considerations would be the safety of maintenance operatives and the safety of members of the public. With potentially a greater maintenance burden, a Larinier fish pass or canalised fish pass may involve greater exposure to risks than the other options. However, it is considered that through design and planning of the maintenance activities the risk can be reduced to an acceptable level. In terms of routine maintenance (i.e. assuming there is no need for works to respond to adjustments in the river), options would therefore rank as follows, starting with the lowest risk.

1. Partial rock ramp (Option 1) – least likely to require clearance of blockages
2. Canalised fish pass (Option 4) – may require clearance of blockage but is easily accessible
2. Right bank Larinier fish pass (Option 3) – may require clearance of blockage but is easily accessible
3. Central Larinier fish pass (Option 2) – may require clearance of blockage and requirement for access structure makes it more difficult to access different parts of the structure

From a public perspective, a partial rock ramp would be inherently safer as it would not involve any vertical drops and it would remove a large section of the vertical drop currently present at the weir. However it is considered that a Larinier fish pass or canalised fish pass would not significantly change the H&S risks at the site relative to current conditions, and any residual risks could be reduced to an acceptable level. The options would rank as follows, starting with the lowest risk.

1. Partial rock ramp (Option 1) – arguably an improvement to safety of local area with removal of vertical drops from weir
2. Central Larinier fish pass (Option 2) – away from river bank so access is discouraged; little change from present situation
3. Canalised fish pass (Option 4) – close to river bank and introduces additional vertical drops

3. Right bank Larinier fish pass (Option 3) – close to river bank and introduces additional vertical drops

In light of the above, it is considered that a partial rock ramp would involve the least H&S risk, as the main risks are one-off during construction. H&S considerations do not differ significantly between options, and it is considered that the H&S risks for any of the options could be managed to an acceptable level. H&S is therefore unlikely to be a deciding factor when choosing between the options.

6. OPTION APPRAISAL STAGE 1: PASS/ FAIL ASSESSMENT

6.1 Overview

Stage 1 of the Option Appraisal is presented in this section. Stage 1 is a pass / fail step, with options failing if they result in any of the following:

- Increased flood risk to property that cannot be mitigated;
- Unacceptable health and safety risks that cannot be mitigated; and
- Unacceptable change to channel stability (e.g. channel planform could vary which could compromise structures or surrounding infrastructure).

6.2 Flood Risk to Buildings

The modelling indicates that the buildings are not at risk of flooding during a 200 year return period flood event, including an allowance for climate change. The canalised fish pass and Larinier options would not change flood risk. The effect of the partial rock ramp diminishes with increasing flows, meaning there may be no impact on the kind of flows that would cause residential property flooding (i.e. greater than 200 year return period plus climate change). Further investigation in terms of extreme flows would be required should this option be further developed, however for the purposes of this option appraisal it is assumed that there is no change to flood risk to buildings resulting from the partial rock ramp.

6.3 Health and Safety

There are considered to be no health and safety issues that are unacceptable or cannot be mitigated both in terms of construction and operating of any of the fish passes. There are differences between the options both in terms of health and safety and buildability and these are covered in sections 8.7 and 8.8.

6.4 Channel Stability

The River Almond at Mid Calder is confined downstream of the weir and not an active gravel bedded river (i.e. not one with eroding bed and banks as a river moves across its floodplain). The weir also serves to stabilise (fix) the channel and trap any bedload movement.

Historically there has been erosion beyond a natural width for tens of metres below the weir. This has increased the channel width making it less susceptible to change (with stream power being spread across a wider area). Since widening the channel has attempted to adjust to the human pressure of the weir by narrowing through gravel/ cobble deposits, and likely forming the island between the main and secondary channels. The island is stabilised by vegetation and in particular trees and there is little or no evidence of erosion during a flood. Further downstream the channel is confined within a valley and not active.

The options for fish passage are likely to have an initial localised effect (e.g. local scour that could be mitigated through some riprap installation) and not result in channel instability or affect infrastructure or other structures.

As such, it is considered that each option passes this criterion.

6.5 Stage 1 Summary

None of the options failed to meet Stage 1 of option appraisal and so each has progressed to Stage 2.

7. OPTION APPRAISAL STAGE 2: KEY PROJECT CRITERIA

7.1 Overview

Stage 2 of the Option Appraisal is presented in this section.

Options were examined with regard to key project criteria (essentially that the scheme would result in successful fish passage while considering costs), these being:

- Fish passage: ability for multiple species to use the pass;
- Fish passage: issues linked to multiple passage routes;
- Construction cost; and
- Maintenance burden (operational costs).

7.2 Fish Passage

Fish passage is discussed in Section 5.3. The review found that on balance of the above discussion, it is considered that a partial rock ramp would offer the greatest fish passage benefits. This option is not without drawbacks, but mitigation options exist to address these to a certain extent. Either Larinier fish passage options would overall provide the second best option for fish passage and in some respects are more favourable to the partial rock ramp. The canalised fish pass option would provide a means for successful fish passage though it has significant drawbacks associated with it, when compared to any of the other 3 options, and is considered sub-optimal.

Table 7.1 Ranking and relative benefits and disbenefits of the different fish passage options

Option and Rank	Relative Benefits	Relative disbenefits
1 Partial Rock Ramp (Option 1)	Ability or provide multiple flow routes and passage for multiple species	Two upstream migration routes with fish that pass up the secondary flow channel facing a likely dead end)
2= Central Larinier (Option 2)	Entrance at weir face minimising fish searching for this Entrance (downstream end) located at main attractant flow	Pass is small relative to weir length and so fish may need to travel along it to find the pass (especially if they travel up the secondary channel or banks)
2= Right bank Larinier (Option 3)	Entrance at weir face minimising fish searching for this Entrance adjacent to river bank which is a common migration route	Pass is small relative to weir length and so fish may need to travel along it to find the pass (especially if they travel up the secondary channel or centre of the main channel)
4 Canalised fish pass (Option 4)	Ability to provide varied flow conditions for multiple species migration across its 3m width (though less variability than partial rock ramp)	Three upstream migration routes with fish pass entrance far downstream of weir, suggesting this option would be sub-optimal with regard to fish passage

7.3 Costs

7.3.1 *Construction*

Construction costs are discussed in section 5.5.3. It is considered that the partial rock ramp would be the highest cost option. Based on the high-level assessment, it is not possible to distinguish between the likely construction costs of the other three options. More developed designs would allow for quantities to be estimated and the uncertainty in cost estimates reduced. The construction cost summaries and option ranking is presented in Table 7.2.

Table 7.2 Construction costs and ranks

Option and rank	Construction cost estimate
1= Central Larinier (Option 2)	£400,000 - £600,000
1= Right bank Larinier (Option 3)	£400,000 - £600,000
1= Canalised fish pass (Option 4)	£400,000 - £600,000
4 Partial Rock Ramp (Option 1)	£600,000 - £800,000

7.3.2 *Operational*

Discussion on the maintenance burden is included in section 5.6. It is understood that a key consideration for WLC is the maintenance costs, as specific funding is available for capital works but not maintenance. An inability to maintain a fish pass has the potential to prevent it from functioning as intended in the long run.

On balance, it is considered that a Larinier or canalised fish pass would be more likely to attract greater maintenance costs and this would narrow the difference in whole life costs between these and the partial rock ramp. This is due to an increased requirement for debris clearance and future asset replacements (eel passes). None of the options would be maintenance free, however. Due to site-specific characteristics which are yet to be determined or realised (e.g. the quantity of sediment and debris moving through the system), as well as an element of chance, there is some uncertainty in the actual maintenance burden of the options.

It is considered unlikely that maintenance costs would be so much greater for the Larinier or canalised fish pass options that it would make the whole life cost greater than that for a partial rock ramp. Rather than providing a choice between options, however, it is suggested that maintenance needs should guide design of the option, as each option can be designed to minimise the maintenance burden.

Due to the above uncertainties and with limited information available, it was not considered appropriate to provide estimates of maintenance costs. The maintenance (operational) burden option ranking is presented in Table 7.3.

Table 7.3 Maintenance burden ranking

Option and rank	Comment
1 Partial Rock Ramp (Option 1)	Likely smallest maintenance burden although access may not be as straightforward as bankside options
2= Right bank Larinier (Option 3)	Likely greater maintenance burden but straightforward access from river bank
2= Canalised fish pass (Option 4)	Likely greater maintenance burden but straightforward access from river bank
4 Central Larinier (Option 2)	Likely greater maintenance burden and access somewhat more challenging

7.4 Stage 2 Summary

The review of the fish passage performance indicates that the partial rock ramp option would likely be the most favourable followed by either of the Larinier fish pass options. Neither option is without drawbacks, and both options would be considered acceptable and deliver the project objectives. The canalised fish pass is considered sub-optimal with regard to delivering fish passage, especially when compared to the alternative options.

The construction costs for a partial rock ramp are likely to be greater than the other options, although maintenance costs are likely to be lower. However it is considered unlikely that the difference in maintenance costs would be such that the other options would have a higher whole-life cost than the partial rock ramp, but it may close the gap somewhat. It is noted that low operational cost is a key driver for WLC, however it is considered that the strength of evidence is insufficient for this to be a compelling differentiator.

There is little to choose between the partial rock ramp and Larinier options at this stage; the former may be better from a fish passage perspective albeit at a higher cost. Consideration of the criteria in the Stage 3 appraisal may provide a clearer preferred option. At the end of Stage 2 the canalised fish pass appears unfavourable (with fish passage performance being sub-optimal).

8. OPTION APPRAISAL STAGE 3: OTHER CRITERIA

8.1 Overview

Stage 3 of the Option Appraisal is presented in this section. In Stage 3 options were examined with regard to the following important criteria:

- Other ecological effects – do the options have any impacts (positive or negative) on ecology other than fish?
- Flood risk to land and Powie's Path – do the options alter the risk of flooding?
- Hydromorphological effects – do the options alter the hydromorphology of the river?
- Land ownership – do the options require construction on land not owned by WLC?
- Aesthetic effects – do the options result in visual changes that may be attractive or unappealing?
- Buildability and risk – how easily can the fish passes be constructed and what are the risks that could increase construction costs?
- Health and safety – what are the safety considerations during construction, maintenance and operation?
- Risk of poaching – how does the risk of poaching compare between the options?

As outlined in Section 4.3.4, scoring for each topic was as follows:

- +3 major beneficial effect
- +2 moderate beneficial effect
- +1 minor beneficial effect
- 0 neutral effect
- -1 minor adverse effect or complications
- -2 moderate adverse effect or complications
- -3 major adverse effect or significant complications

8.2 Other Ecology

Based on the review set out in Section 5.4, a summary of the scores for other ecological effects are presented in Table 8.1.

Table 8.1 Summary of Other Ecological effects and score

Option	Ecological effects
Partial Rock Ramp	-2 (larger footprint = woodland and aquatic habitat loss, possible impacts on bat, otter and invasive plants; occasional drying of channel may impact aquatic fauna)
Larinier fish pass (central)	0 (minimal habitat loss and reduced potential impacts on fauna)
Larinier fish pass (right bank)	-1 (footprint of bankside structure would be mostly on weir and apron. May affect small area of woodland and aquatic habitat and tree with bat roost suitability)
Canalised fish pass	-2 (larger footprint = woodland and aquatic habitat loss, possible impacts on bat, otter and invasive plants; occasional drying of channel may impact aquatic fauna)

8.3 Flood Risk to Land and Powie's Path

As described in section 5.2.2, the Larinier and canalised fish pass options would have no effect on flood risk. Some changes to water levels would occur with a partial rock ramp in place however this is not considered to present any significant impacts, concerning only flooding of land that is already at risk of flooding. The frequency with which Powie's Path would be flooded would not be affected by the options, although the extent of flooding may change. The scoring for this criterion is provided in Table 8.2 below.

Table 8.2 Summary of flood risk scores

Option	Hydro- morphological effects
Partial Rock Ramp	-1 (risk identified with current modelled design- can potentially be removed through design)
Larinier fish pass (central)	0
Larinier fish pass (right bank)	0
Canalised fish pass	0

8.4 Hydromorphology

Our hydromorphological appraisal of the potential effects of each option on hydromorphology was described in Section 5.2. The scoring for this criterion is provided in Table 8.2 below.

Table 8.3 Summary of hydromorphological effects and score

Option	Hydro- morphological effects
Partial Rock Ramp	-2 (potential effects include redirection of flow onto a bank or specific part of the bed causing erosion, reduction of capacity by the works, causing erosion elsewhere in the section and inducing instability of bare earth banks by concentrating flows through secondary channels while mitigation may not be possible due to land ownership constraints etc.)
Larinier fish pass (central)	0 (negligible effects predicted)
Larinier fish pass (right bank)	0 (potential effects include redirection of flow onto a bank or specific part of the bed causing erosion and mitigation has been included to mitigate this effect)
Canalised fish pass	-1 (potential effects include reduction of capacity by the works, causing erosion elsewhere in the section and inducing instability of bare earth banks by concentrating flows through secondary channels - mitigation has been included but some uncertainty remains)

8.5 Land Ownership

Options that can entirely be undertaken from WLC owned land would be easier to deliver. A review of land ownership and the potential effect on the deliverability of the options is presented in Table 8.4 below.

Table 8.4 Summary of land ownership review and score

Option	Land ownership review and score
Partial Rock Ramp	-2 (option would require construction on land not owned by WLC)
Larinier fish pass (central)	0 (scheme on WLC owned land)
Larinier fish pass (right bank)	0 (scheme on WLC owned land)
Canalised fish pass	0 (scheme on WLC owned land)

8.6 Aesthetics

Each of the four options could have a noted effect on the visual appearance of the weir and its environs. Judging the potential effect of this can be quite subjective, however. Some potential visual effects, that could be considered adverse or beneficial to different users include:

- ancillary structures such as access platforms may be considered (associated with the central Larinier option/ Option 2, see Section 3.3);
- a notable change in the appearance of the weir and channel (associated with the partial rock ramp / Option 1); and
- drying of the main or secondary channels compared to the baseline situation (discussed in Section 5.1).

A review of potential aesthetics effects has been undertaken and is presented in Table 8.5 (noting that others may have different views).

Table 8.5 Summary of aesthetic effects review and score

Option	Aesthetic effects*
Partial Rock Ramp	-1 (Significant change to appearance of river and weir compared to current visible from both banks, although it should have a relatively natural appearance. Ramp may block off view of the wider river from the left bank, although access and visibility is limited.)
Larinier fish pass (central)	-1 (fish pass in channel with ancillary access platforms would disrupt the open views of the river particularly when viewed from the right-hand bank)
Larinier fish pass (right bank)	1 (fish pass on right-hand bank would have a small footprint and may blend reasonably with the "industrial" appearance of the weir)
Canalised fish pass	-2 (visible primarily from the right-hand river bank. Drying of the major channel during dry period would have a noticeable impact on the character of the river, as would a long wall down the river bank)

8.7 Buildability and Risk

Buildability is dependent on a large number of factors and an overall assessment of the buildability of any given option would be based on some judgement of the relative importance of each of the factors. Table 8.6 below sets out a number of buildability considerations with commentary against each option. For each component the options are ranked against one another (with 1 being the "most buildable" option). An overall buildability score is provided at the bottom of the table.

Table 8.6 Buildability Review of the Fish Pass Options and Scoring

Factor	Option 1: Partial rock ramp	Option 2: Larinier fish pass (central)	Option 3: Larinier fish pass (right bank)	Option 4: Canalised fish pass
Access to site	All options would involve the same access arrangement via land to the south.			
Access into river	Ramped access for earth-moving equipment required (=2/4)	Ramped access for construction equipment required (=2/4)	Construction could mostly take place from river bank (1/4)	Access required along long length of channel (4/4)
Extent of temporary works	Significant width and length – would require flood risk check (4/4)	Significant width but small length (3/4)	Small width and length (1/4)	Small width but significant length (2/4)
Nature of temporary works	Extensive area but relatively shallow water. May need to cross island to prevent flow into working area from secondary channel. Could be achieved with tonne bags (3/4)	Deep water upstream of weir likely requiring a frame dam out to middle of river (4/4)	Smaller area downstream of weir easily isolated with tonne bags or similar (1/4)	Extensive area but relatively shallow water. Could be achieved with tonne bags (2/4)
Scale of the work	Major works with large volume of materials (4/4)	Less extensive but more time-consuming work (reinforced concrete) (=1/4)	Less extensive but more time-consuming work (reinforced concrete) (=1/4)	Less material required than for partial rock ramp, but significant length of reinforced concrete (3/4)
Complexity of work / specialist nature	Attention to detail required for low flow channel and weir interface (=3/4)	Requires cutting into weir (2/4)	Installed downstream of weir (1/4)	Attention to detail required throughout due to narrow nature of channel (=3/4)
Design risks	- interface with island and banks - interface with weir - impacts on trees (=3/4)	- Cutting into weir - Forming pool downstream of weir (=1/4)	- Less cutting into weir - Works to abutment and apron (=1/4)	- Impacts on trees - Interface with abutment - Interface with river banks (may need more retaining structures) - Foundations for retaining wall (=3/4)
Requirement for heavy plant / cranage	No significant difference between the options. Options involving reinforced concrete (all except partial rock ramp) could make use of precast sections. This apparent disbenefit would be countered by reduced in-river working.			

Factor	Option 1: Partial rock ramp	Option 2: Larinier fish pass (central)	Option 3: Larinier fish pass (right bank)	Option 4: Canalised fish pass
Resilience of works to flooding	Experience at Howden and Fair-a-Far suggests that in-progress works are likely to be relatively resilient to flooding for all options			
Interface with public	All options would involve the same level of disruption to the riverside footpath			
Overall buildability score	**-2**	**0**	**1**	**-1**

Ultimately, the best option from a buildability perspective is considered to be a river bank Larinier fish pass, whereas the worst would be a partial rock ramp. The other two options would fall together somewhere in between. There are not considered to be any buildability issues that cannot be overcome for a partial rock ramp, but it is certainly the more challenging structure on the whole.

8.8 Health and Safety

Health and safety considerations are discussed in section 5.7. For the purposes of scoring, construction-phase risks were given a lesser weighting as they are one-off and can be managed by an experienced contractor. Construction-phase issues are also covered in the buildability section (section 8.7).

Table 8.7 Health and safety scoring

Option	Health and Safety
Partial Rock Ramp	1 (main risks are during construction, and removal of vertical drops near footpath reduces public safety hazards)
Larinier fish pass (central)	0 (no significant change from baseline)
Larinier fish pass (right bank)	0 (no significant change from baseline)
Canalised fish pass	0 (no significant change from baseline)

8.9 Poaching

Poaching has previously been expressed as a key concern by members of the steering group. Due to the threat of poaching, the outline design of the Larinier fish pass included a mid-channel position. A canalised rock ramp would be most vulnerable to poaching, with a narrow channel including pools in secluded locations. A Larinier fish pass constructed next to the river bank could also be vulnerable. A partial rock ramp or mid-channel Larinier fish pass would present a greater challenge to poachers. In each case, there are mitigation options available to reduce the risk e.g. the use of covers (although these may have safety / maintenance considerations), fencing (potential visual impacts) or monitoring.

A summary of scoring with regard to the risk of poaching is provided in Table 8.8.

Table 8.8 Poaching scoring

Option	Risk of Poaching
Partial Rock Ramp	-1
Larinier fish pass (central)	0
Larinier fish pass (right bank)	-2
Canalised fish pass	-2

8.10 Stage 3 Summary

A summary of the Stage 3 scoring is provided in Table 8.9 below. This indicates that either Larinier option performs relatively neutrally with regard to the 8 other important criteria outlined in Stage 3. There are risks or challenges associated with the canalised fish pass for five of the eight criteria and for seven of the eight criteria for the partial rock ramp option.

Table 8.9 Summary of Stage 3 Option Appraisal

Criteria	Score for each option			
	Partial Rock Ramp	Larinier fish pass (central)	Larinier fish pass (right bank)	Canalised fish pass
Other ecology	-2	0	-1	-2
Flood risk to land	-1	0	0	0
Hydromorphology	-2	0	0	-1
Land ownership	-2	0	0	0
Aesthetics	-1	-1	1	-2
Buildability	-2	0	1	-1
Health and safety	1	0	0	0
Poaching	-1	0	-2	-2

9. OPTION APPRAISAL SUMMARY

9.1 Appraisal Summary

Four options were considered as part of a three stage option appraisal process. These were:

- A partial rock ramp, as developed in recent work;
- A Larinier fish pass towards the middle of the river channel, as developed in 2016 to outline design level, but including further considerations as described in this report;
- A Larinier fish pass adjacent to the right-hand bank, similar to that installed at Fair-a-Far weir in Cramond, Edinburgh. A concept design was developed for this report to allow the option to be appraised; and
- A canalised fish pass along the right-hand bank. A concept design was developed for this report to allow the option to be appraised and informed by a similar fish pass at Hoghton Bottoms weir (Ribble Rivers Trust).

Stage 1 of the Option Appraisal was a pass / fail step, with options failing if they resulted in any of the following:

- Increased flood risk to property that cannot be mitigated;
- Unacceptable health and safety risks that cannot be mitigated; and
- Unacceptable change to channel stability (e.g. channel planform could vary which could compromise structures or surrounding infrastructure).

On review each of the four options passed the Stage 1 assessment; there are no insurmountable barriers to the implementation of any of the options. As such each option progressed to Stage 2.

Stage 2 of the Option Appraisal examined each option with regard to key project criteria (essentially that the scheme would result in successful fish passage while considering costs), these being:

- Fish passage: ability for multiple species to use the pass;
- Fish passage: issues linked to multiple passage routes;
- Construction cost; and
- Maintenance burden (operational costs).

The review of the fish passage performance indicated that the partial rock ramp option would likely be the most favourable followed by either of the Larinier fish pass options. Neither option would be without drawbacks, and both options would be considered acceptable and deliver the project objectives. The canalised fish pass is considered sub-optimal with regard to delivering fish passage, especially when compared to the alternative options.

The construction costs for a partial rock ramp are likely to be greater than the other options, although maintenance costs are may be lower. However it is considered unlikely that the difference in maintenance costs would be such that the other options would have a higher whole-life cost than the partial rock ramp, but it may close the gap somewhat. It is noted that low operational cost is a key driver for WLC, however it is considered that the strength of evidence is insufficient for this to be a compelling differentiator.

At the end of Stage 2 it was considered that there was little to choose between the partial rock ramp and Larinier options at this stage; the former may be better from a fish passage perspective albeit at a higher cost. At the end of Stage 2 each of the four options was considered in Stage 3 (noting that at the end of Stage 2 the canalised fish pass appeared to be unfavourable with fish passage performance being sub-optimal).

Stage 3 of the Option Appraisal examined each option with regard to the following important criteria:

- Other ecological effects – do the options have any impacts (positive or negative) on ecology other than fish?

- Flood risk to land and Powie's Path – do the options alter the risk of flooding?
- Hydromorphological effects – do the options alter the hydromorphology of the river?
- Land ownership – do the options require construction on land not owned by WLC?
- Aesthetic effects – do the options result in visual changes that may be attractive or unappealing?
- Buildability and risk – how easily can the fish passes be constructed and what are the risks that could increase construction costs?
- Health and safety – what are the safety considerations during construction, maintenance and operation?
- Risk of poaching – how does the risk of poaching compare between the options?

Each criterion may be associated with a benefit or disbenefit and / or may result in particular challenges to the delivery of the project.

During the Stage 3 review either Larinier option performed relatively neutrally with regard to the 8 other criteria outlined in Stage 3; better than the other two options. There are risks or challenges associated with the canalised fish pass for five of the eight criteria (these being other ecology, hydromorphology, aesthetics, buildability and poaching) and for seven of the eight criteria for the partial rock ramp option (these being other ecology, flood risk to land, hydromorphology, land ownership, aesthetics, buildability and poaching).

9.2 Conclusions and Recommendations

At the end of Stage 2 it was considered that there was little to choose between the partial rock ramp and Larinier options at this stage; the former may be better from a fish passage perspective albeit at a higher cost. However, a number of potential disbenefits and challenges linked with the partial rock ramp were apparent during Stage 3 of the Option Appraisal across most of the other criteria considered. For this reason it is considered that a Larinier fish pass would be most appropriate at Mid Calder. This is AECOM's position based on the appraisal presented here; it is noted that other parties may favour a different option as they may place a greater emphasis on certain criteria.

Based on fish passage performance, project costs and the criteria assessed in Stage 3 of the appraisal there is little to choose between whether a central or right bank Larinier fish pass is selected. Relative differences may inform the final choice on siting (e.g. if poaching risks or potential aesthetics effects are considered to be more important).

The canalised fish pass performed less well than either Larinier option through Stages 2 and 3 of the Option Appraisal and is not recommended at Mid Calder weir.

A number of challenges and disbenefits would need to be overcome if the partial rock ramp were progressed, based on the results of the Option Appraisal. This may result in escalating costs and project delays. The design of a partial rock ramp could be adjusted to mitigate certain challenges although this could create new issues. For example the width of the rock ramp could be reduced so that it does not extend to the island (similar to significantly widening the canalised fish pass). However, this may necessitate inclusion of a retaining wall, which could increase project costs, create an additional dead end for migrating fish and be a source of erosion of the channel between the island and wall.

For whichever option is selected further design and assessment would be required as part of a detailed design, particular where potential risks, challenges and disbenefits have been identified during this Option Appraisal.

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Appendix A – Relevant Experience from Other Fish Passes

A.1 Kirkton Weir

Detailed design and construction of the Kirkton Weir Larinier fish pass occurred in 2017. The following text outlines some of the design considerations that may come to light during detailed design of a Larinier at Mid Calder Weir.

Figure A1.1 below indicates a number of considerations that emerged during the early stages of the detailed design. A pool is required downstream of the Larinier to ensure that power in the water flowing down it is suitably dissipated so as not to discourage fish from travelling up it.

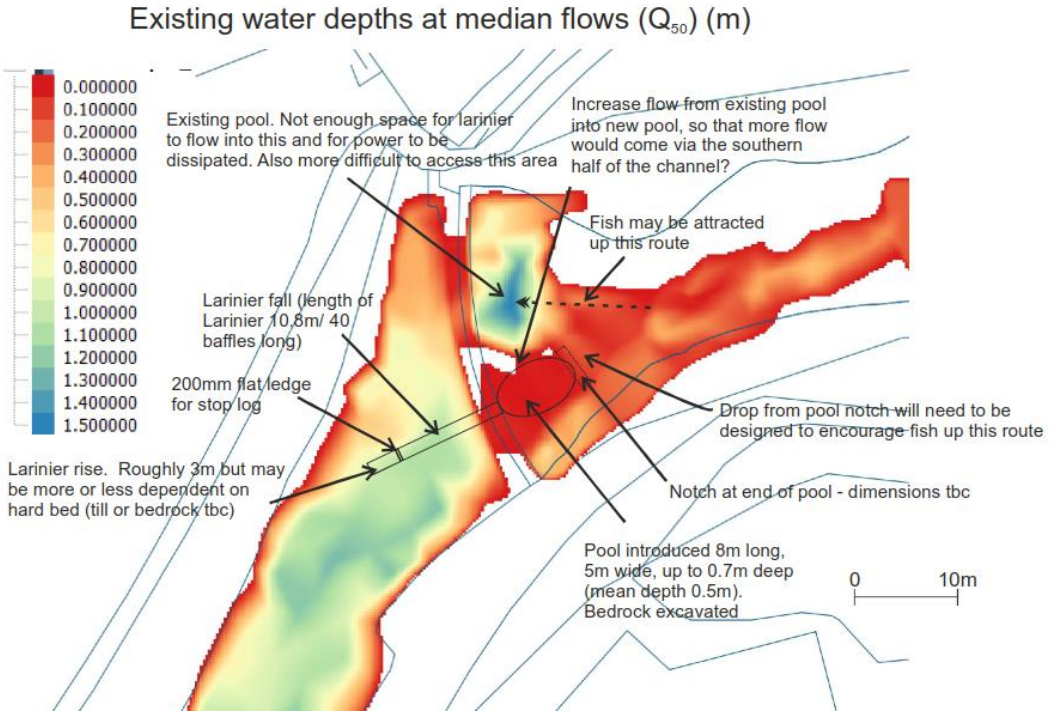

Figure A1.1 Kirkton Weir design considerations during the detailed design phase

The project and design team were aware that inclusion of a pool was far from ideal due to risks of poaching. A pool is a crucial component of a design that would fulfil its purpose of facilitating fish passage and ultimately the pool was included in the final design. The pool discharged via a channel at its downstream exit.

The Larinier fish pass channel included a lamprey plate while a separate eel pass was constructed in 2019 on the right-hand side of the channel. A maintenance access platform was designed and built after the fish pass had been built. This was due to the larger size and volume of debris, as well as difficulties removing this from the middle of the channel.

During construction, it was necessary to move the fish pass closer to the right bank to create space for the large temporary works needed to hold back a significant depth of water.

Images of the constructed Larinier fish pass and eel pass are provided in Plates A1.1 to A1.4.

Plate A1.1 Kirkton Weir with in channel Larinier looking downstream

Plate A1.2 Kirkton Weir with in channel Larinier looking across the channel/ weir

Plate A1.3 Access walkway and platform (added in 2018 after Larinier had been built)

Plate A1.4 Eel pass at right-hand side of the channel (built in 2019)

A.2 Fair-a-Far Weir

The table below shows some post-construction issues that have been identified by City of Edinburgh Council and Forth Rivers Trust. A commentary on whether the issue can be resolved and the extent to which it is applicable to Mid Calder is also included.

Table A.2 Post Construction Issues reported at Fair a Far Weir bankside Larinier fish pass

Issue	Comment
Loose baffles	AECOM is awaiting confirmation of which baffles are loose and details of fixings. Larinier fish passes have been used across the country without such issues so this is considered to be a site-specific issue (e.g. wrong screws specified or used, incorrect installation) that should not apply to a Larinier fish pass at Mid Calder.
Eel pass clogging and covers being dislodged	The location and nature of the eel pass (small concrete channel with covers) makes it prone to blockage. Alternative eel pass designs are possible and these could be considered at Mid Calder, in addition to debris management (e.g. deflectors). The position of the fish pass at Fair-a-Far makes maintenance and inspection challenging.
As-built information (i.e. are they representative)	Based on the information available to AECOM at the time, it was considered that the Contractor carried out the requirements of the Works Information so the as-built drawings were based on the last construction issue drawings.
Flow conditions at upstream end	Sub-optimal flow conditions exist at the upstream end of the fish pass. This is potentially due to the fish pass exist not being aligned with the local direction of flow, or the geometry of the structure itself. This has not been an issue at other Larinier fish passes and it is therefore considered that this is a site-specific issue that should not apply at Mid Calder. That said, a river bank location at Mid Calder would require more detailed consideration as the flow patterns may be more complex compared with a central location.
Stop log grooves not aligned	AECOM is awaiting further information regarding this issue however this would be a site-specific issue that should not apply at Mid Calder. Alternative stop log / monitoring arrangements could be considered at Mid Calder.
Finished levels	There have been suggestions that finished levels of the fish pass are not as designed. This is an area of on-going investigation but if there is an issue, this should be a site-specific similar to the loose baffles.

In summary, it is considered that none of the issues experienced at Fair-a-Far are likely to affect the feasibility of a Larinier fish pass at Mid Calder. There are some useful lessons to be learnt that could be applied to either a central or river bank arrangement. A river bank arrangement is likely to require more detailed consideration, but it should be possible to avoid the problems experienced at Fair-a-Far.

A.3 Hoghton Bottoms Weir

Following the stakeholder meeting AECOM were advised by WLC of a potential alternative fish pass which could be constructed at the site. This option is referred to as a "canalised fish pass".

The fish pass is relatively rare in the United Kingdom and not included in the Environment Agency Fish Pass Manual. The project team became aware of a canalised fish pass that has been constructed by the Ribble Rivers Trust at Hoghton Bottoms Weir on the River Darwen near Blackburn, Lancashire. Design drawings were obtained for the fish pass along with a supporting report to inform a potential design at Mid Calder Weir[14]. It was recognised by the Ribble Rivers Trust that constraints resulted in the fish pass not meeting typical design criteria, however it was felt that the fish pass would offer useful context to such a potential solution at Mid Calder weir.

A review of available information indicated the following:

- Canalised fish pass was built on an existing bedrock outcrop.
- The head drop between the weir and first pool downstream of the pass is 3m.
- The pass has a slope of 1:6 (16.67%) and has been sited on the left hand side (looking downstream) of the channel. It is downstream of the weir where space was confined by the presence of a large bedrock outcrop and downstream bend in the channel banks. The fish pass slope is much steeper than that recommended by the Fish Pass Manual for ramps (5%)15 and that indicated in the DVWK guidance16, that has been used to inform the design for the pass Hoghton Bottoms weir. There are no constraints at Mid Calder that would necessitate such a steep structure.
- The fish pass channel is approximately 2.5m wide and an informal low flow channel was indicated on the drawings though was to be realised by careful placement of boulders and is not readily discernible on the drawings.
- A notch into the weir approximately 200mm deep and 600mm wide is included at the top of the pass.
- A small retaining wall was included on the drawings, less than 400mm above ramp levels. This may be little more than water levels in the fish pass under most flow conditions.

A representative from WLC visited the site on the 11 October 2019 although this was at a time of high flow when the fish pass was submerged (see Plate A3.1). AECOM visited the site on the 29 October 2019 when the pass was viewable; images from this visit are provided below as Plates A3.2 to A3.6.

Plate A3.1 Hoghton Bottoms weir at time of high flow (fish pass to left submerged)/ 11-10-19

Plate A3.2 Canalised fish pass/ 29-10-19

[14] Ribble Rivers Consultancy Report (2016) Fish Passage Appraisal Hoghton Bottoms. RRCL.FPA.20160329.1
[15] Environment Agency (2010) Environment Agency Fish Pass Manual. Formally withdrawn though still used and hosted on other organisations websites, e.g. IFM.
[16] DVWK (2002) Fish Passes Design, Dimensions and Monitoring. English version

Plate A3.3 Darwen downstream of the weir/ 29-10-19

Plate A3.4 Hoghton Bottoms Weir (fish pass to the right)/ 29-10-19

Plate A3.5 Notch in the weir at the top of the pass/ 29-10-19

Plate A3.6 Upstream of the Hoghton Bottoms Weir/ 29-10-19

River Darwen flow data for the site visit was not available yet due to it taking time for the Environment Agency to check data quality etc. prior to release. However long-term river level monitoring on the Darwen was downloaded for the upstream level gauge, the Darwen at Ewood (NGR: SD677262) for the purposes of this assessment. Levels on the 11 October 2019 were 0.821m (equivalent to H_3 – the level exceeded for 3 % of the time). Levels on the 29 October 2019 were 0.398m (equivalent to the H_{37}, exceeded for 37% of the time).

The fish pass observed on the 29 October 2019 looks quite turbulent and it is considered that fish would not be able to traverse up this successfully. Migration for larger species under such medium to moderately high flow conditions should normally be provided and so the fish pass is considered to be sub-optimal on this basis. Water levels in the fish pass channel are approaching the height of the retaining wall too, suggesting that this would be overtopped under high flows. Fish passage would not be expected under the very high flow conditions observed on the 11 October 2019 although the degree of turbulence observed in the channel on the 29 October 2019 suggested it would be excessive even at times of high flow when passage would be expected (e.g. Q_{10}).

Appendix B – Recent Updates to the Hydrological Analysis Tool

Following the 19 September 2019 meeting (see Table 2.1), AECOM were permitted by Charles Corbett to go onto the island and observe the existing fish pass up closer. An image of this is provided as Plate B.1. An image from the surveyors has also since been obtained and is indicated in Plate B.2. These indicate that the notch in the weir into the fish pass is much smaller than assumed for the initial analyses draft design note, based on information collected during the previous Motts survey (see Table 2.1). As such the baseline hydrological situation was revised between the initial partial rock ramp analyses note (August 2019) and November 2019 partial rock ramp design report to account for the smaller dimensions of the notch and the assessment of hydrological effect of the partial rock ramp updated accordingly.

Plate B.1 Fish pass from island/ notch apparent

Plate B.2 Notch up close/ 2019 survey indicating it as measuring 0.6m wide and 0.13m deep