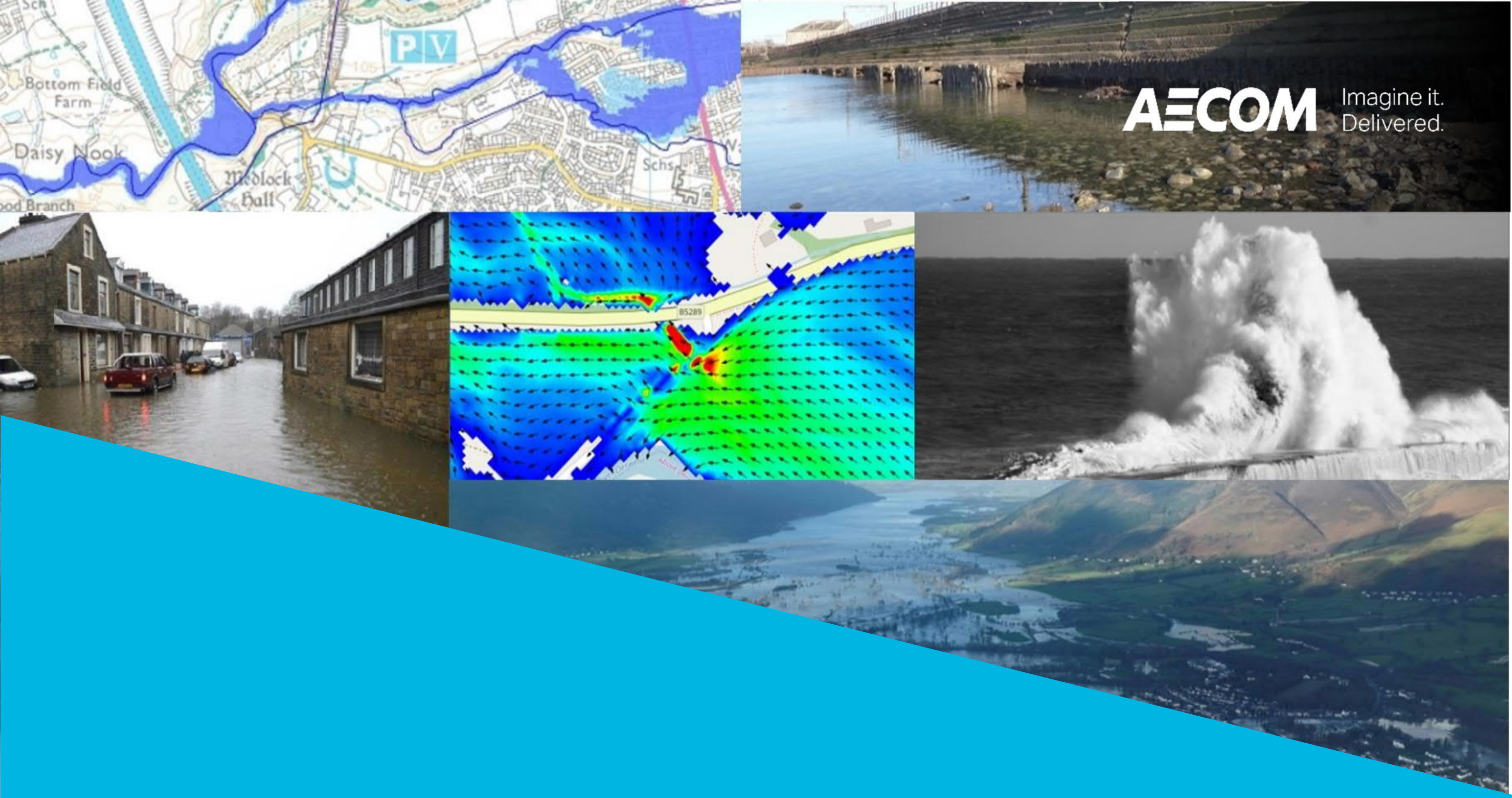

S4T2 Lot 2 – Outline Design

Llanfair Modelling Report and Flood Consequence Assessment

Natural Resources Wales

S4T2-ACM-LLAN-XX-RP-CE-100005

1st April 2021

Cyfoeth Naturiol Cymru
Natural Resources Wales

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
01		Original Doc	Nick Maynard	Nick Maynard	Associate Engineer

Distribution List

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Document overview

AECOM was commissioned by Natural Resources Wales to undertake hydraulic modelling and a Flood Consequence Assessment of the River Elwy at Llanfair Talhaiarn, Conwy to support technical fish pass design under the Salmon for Tomorrow – Lot 2 framework, a scheme which looks to address fish passage issues on rivers throughout Wales.

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1 Introduction

The Salmon for Tomorrow project funded by the European Fisheries Fund and the Welsh Government aims to open up 1,500km of waterways for spawning on river reaches where fish passage is impeded by large weirs. This document provides assessment of weir removal along a 2.3 km stretch of the Afon Elwy (or River Elwy) at Llanfair Talhaiarn, Conwy, Wales carried out by AECOM on behalf of Natural Resources Wales (NRW). At present, the current weir, constructed for milling, impedes fish passage upstream. The structure incorporates a fish pass structure, but it is of a poor design and limits the species able to pass upstream. As a result, the proposed option for the site is a full weir removal with enhanced natural features.

During the initial modelling of the option, it was noted that the drop in water level associated with the weir removal cut off floodplain interaction upstream of the structure. This has the effect of increasing the flow in the downstream channel and potentially increasing erosive potential.

This document presents the analysis and results demonstrating the impact of weir removal on water level and velocity through the study reach. It also includes initial investigation into a number of options to potentially mitigate the increased erosion potential within the study reach.

1.1 Site Overview

The study site is located at Llanfair Talhaiarn in the middle reaches of the River Elwy, situated in Conwy, Wales. The full Elwy catchment (to its tributary with the Afon Clwyd) is approximately 250km², with a 105.5km^2 catchment feeding the study site. The river rises as the Afon Cledwen which has its source approximately 14km south west of the site. At Llangernyw the river becomes the Elwy where the Afon Gallen and Afon Collen join Afon Cledwen. The study site (Figure 1-1), centred around SH 93055 70474, compromises the existing weir which is thought to have been in place for 200 years, possibly more, and is a crump weir, formally used for providing flow to a mill race. The weir (

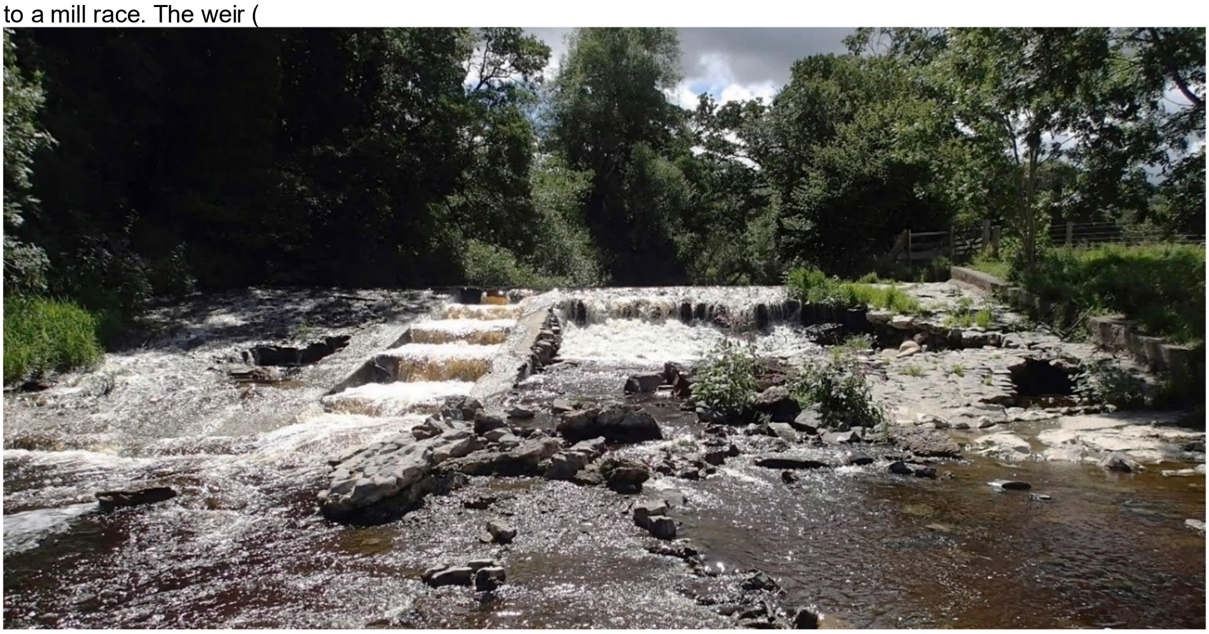


Figure 1-2) is heavily degraded and partially collapsed. The ramp on the left side of the river (looking downstream) has been undercut, resulting in near entire collapse and the bottom of the right ramp is also starting to show a loss of material. The weir drop is approximately 2.5 m. The existing fish pass is in the centre of the channel and functions poorly. It has five steps, each with a height of around 0.5 m which limits the range of species and sizes of individuals able to pass. In addition to this, the partially collapsed nature of the weir will likely create attraction flows away from the fish pass.

Upstream of the weir are two road bridges, the School Lane Bridge dating back to 1766 and the more modern A544 Road Bridge (Elwy Road) built in 1927. The banks downstream of these are steep, tree lined and spill onto the floodplain to the north. There is over 20 km of salmonid spawning habitat upstream of the weir (NRW, 20201), but the weir currently limits migration

In general, the catchment is gently sloping with a DPSBAR of 120.9m/km. The in-channel elevation at the study reach is approximately 101-104.5mAOD. Upstream the catchment rises to 515.5m AOD at its highest point. Land use is predominantly rural (grassland, woodland and mountain/heath), with relatively small urban and arable areas scattered throughout. The catchment is wet compared to the rest of the UK, with a SAAR (standard average annual rainfall) of 1234mm/year. The bedrock geology of the catchment is made up of mudstone, siltstone and sandstone leading to a lower SPRHOST (39.83) and BFIHOST of 0.416. Superficial deposits consist of till in the upper catchment, and alluvium beneath the study site.

1.2 Study Objectives

Following a site visit it was clear that there are significant challenges to improving fish passage. The optioneering process identified a preferred option to remove the weir. This study reports on modelling carried out to identify the benefits of this. The following steps were undertaken:

- A 1D-2D hydraulic model was built;
- The impacts of weir removal on water level and velocity at the site were investigated;
- Initial investigation into potential options to mitigate the impacts of the weir removal; and
- Presentation of the results of the hydraulic modelling, quantifying the impact on velocities and scour.

The hydraulic model required peak flow estimates at the upstream extent of the model and associated hydrograph inflows. The hydraulic model was then used to simulate the 1%, 2% and 10% AEP design flood events. The model has been used to assess potential changes to the depth and velocity of flow, and hence potential benefits to fish passage, following the implementation of the above option.

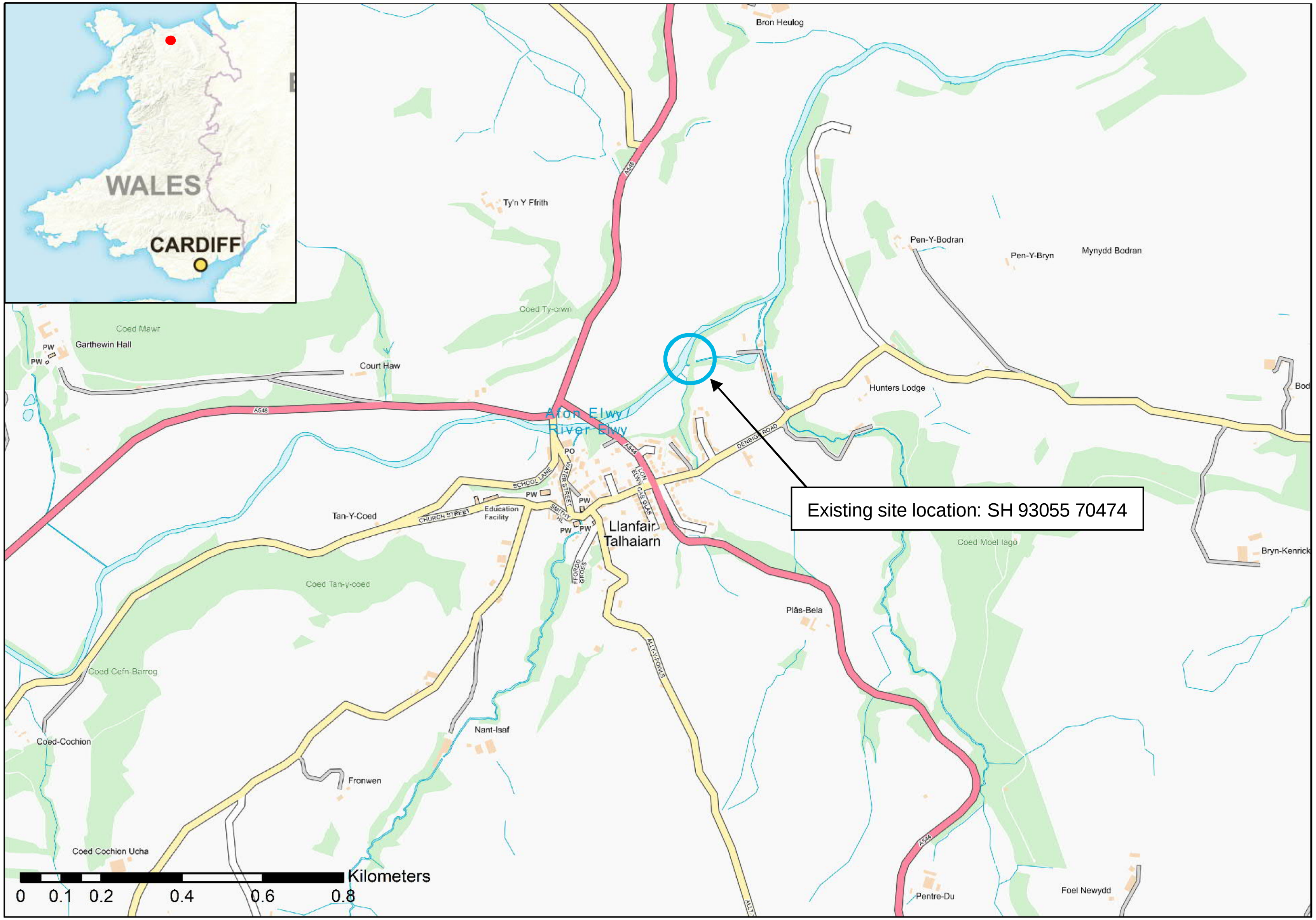


Figure 1-1 Llanfair TH site location

Figure 1-2 Llanfair TH weir from downstream, post collapse

1.3 Data Review

Table 1-1 outlines the data sources used in this study. Further detail on several of these sources is given in the following sections.

Table 1-1 Data sources

Data source	Description
Photographic evidence	A site walkover took place on 28th July 2020 and a visual weir inspection on 18th August 2020. Photographic evidence from these visits was used when considering modelling approach. Photographs were also taken as a part of the topographic survey.
Topographic survey	Topographic survey carried out in August 2020 was supplied.
LiDAR data	LiDAR data was sourced freely, the 2019 1m DTM is used.
Flow data	Flow record and percentile flows provided by NRW for the River Elwy at the Pont Y Gwyddel station.
Hydraulic model data	Two additional Flood Modeller networks were used to extend the new 1D model created from 2020 topographic survey. These include a model created in 2016 to inform options appraisal for the Nant Barrog Water Street culvert upgrade and a hydraulic model supplied by NRW in November 2020.
Hydrologic data	Inflows were estimated using the ReFH2 method. Catchment descriptors were downloaded from the FEH Web Service.

1.3.1 Topographic Survey

A topographic survey was undertaken most recently in August 2020 for use in this study. This included survey of the weir as well as cross section surveys from 150m downstream of the weir to approximately 450m upstream of the weir (Figure 1-3). Further topographic survey was supplied as outlined in Table 1-2. This further survey was used to extend the modelled reach in both the upstream and downstream directions.

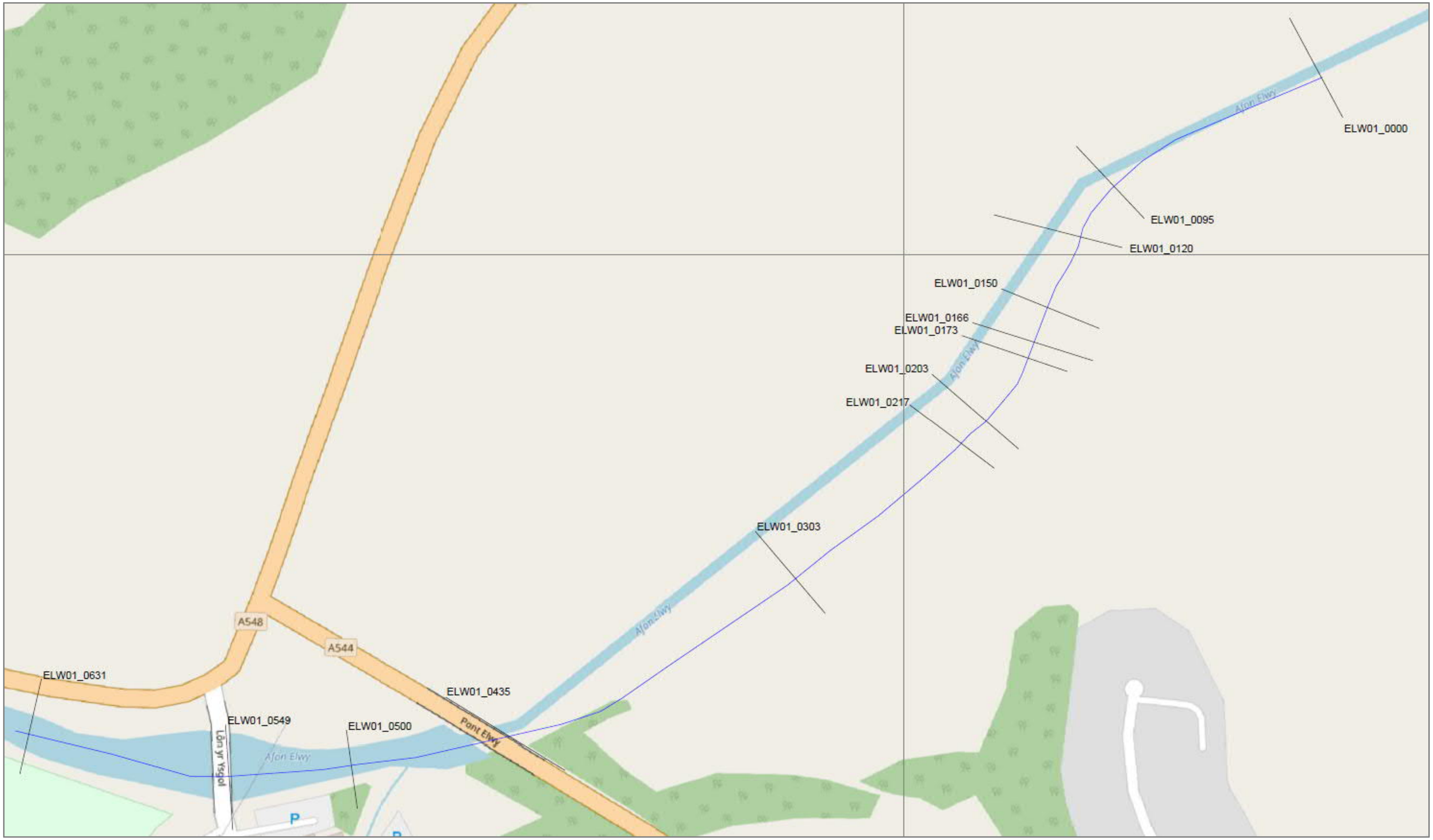


Figure 1-3 Location of August 2020 cross section survey. The weir is located between ELW01_0150 and ELW01_0166.

Table 1-2 Topographic survey supplied

Source	Channel Length (m)	Number of Channel Cross Sections	Number of Structures
2020 Topographic Survey	631m	12	3
Nant Barrog Model	Additional 178m d/s and 393m u/s of 2020 survey	2	0
NRW Model	Additional 1100m d/s of Nant Barrog model addition	6	3

1.3.2 LiDAR Data

LIDAR data (2019 1m DTM composite) has been obtained from open source (Figure 1-4). This was used to understand and represent the topography of the land surrounding the study site.

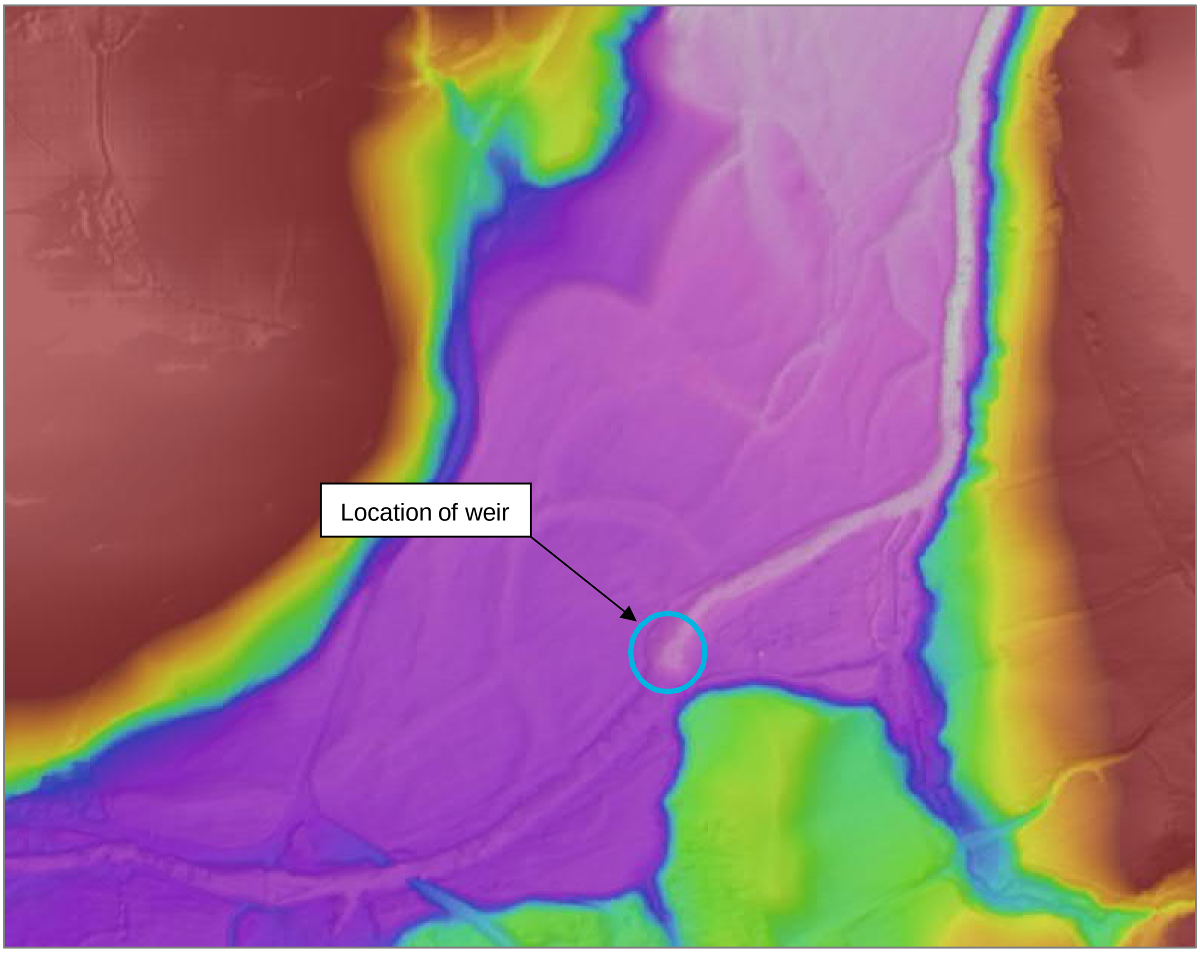


Figure 1-4. LiDAR obtained from NRW

2 Hydrology

Figure 2-1 shows the location of the flow estimation point and associated catchment from the FEH Web Service[1]. The peak flow estimate location is at the weir (NGR SH 93050 70450).

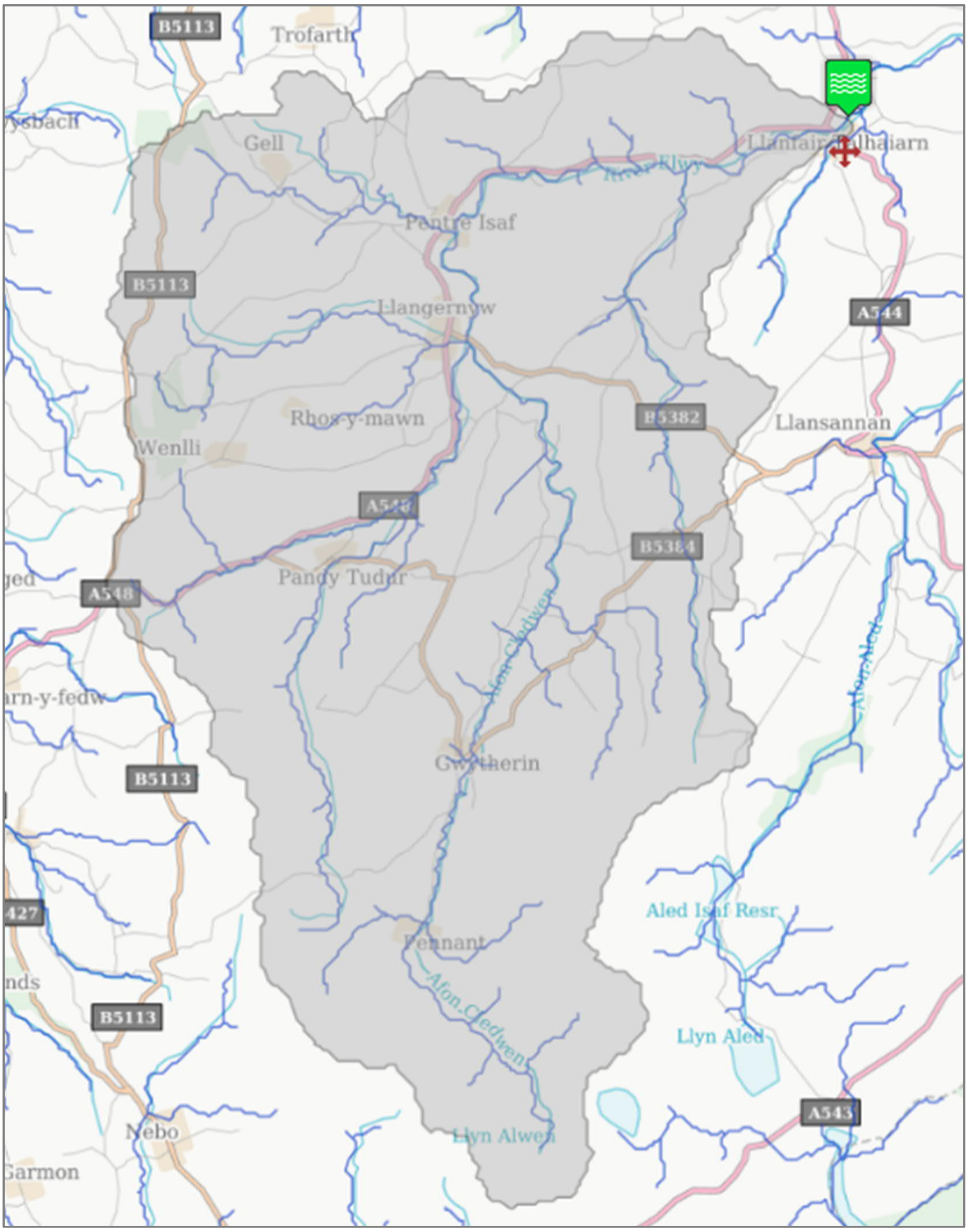


Figure 2-1: Elwy catchment flow estimation point (NGR SH 93050 70450)

The catchment descriptors were downloaded from the FEH Web Service and used in ReFH2 software to generate design hydrographs. Default event parameters were used and flows for a 7.5-hour recommended duration rainfall event were generated for several Annual Exceedance Probabilities (AEP) (Table 2-1). The 1% AEP design event hydrograph is demonstrated in Figure 2-2. The winter, rural event was extracted as the catchment is flashy due to its rural nature.

[1] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK. Available at: https://fehweb.ceh.ac.uk/

Table 2-1 Peak flows from ReFH2 design events

AEP	Peak Flow (m³/s)
1%	128.60
2%	107.49
10%	68.21

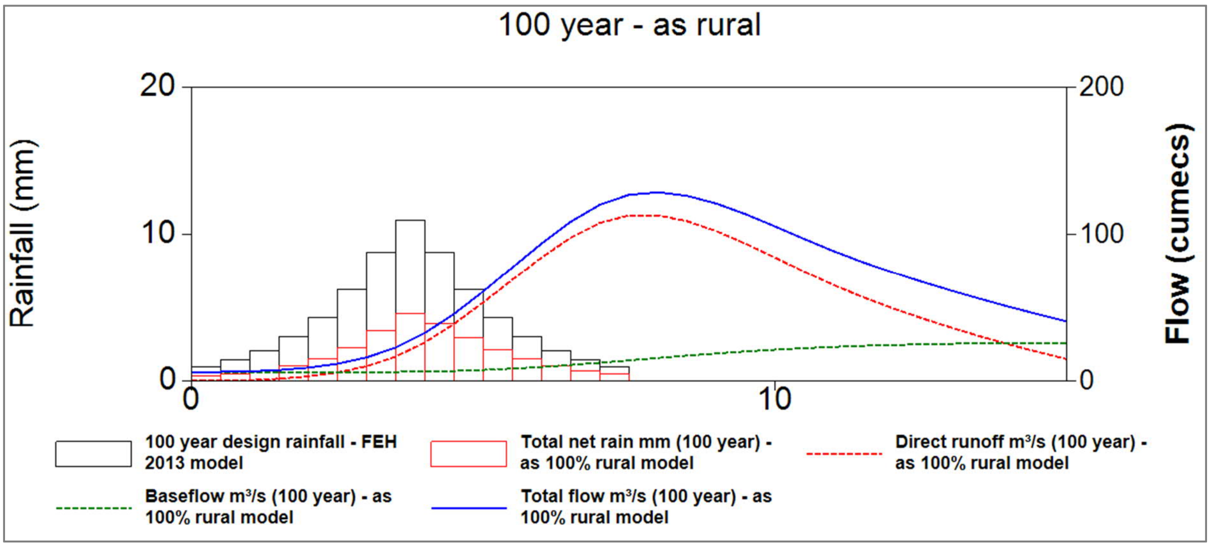


Figure 2-2 ReFH2 100-year design event

3 Hydraulic Modelling

3.1 Model Schematisation

A new 1D-2D hydraulic model has been developed in this project, using TUFLOW and Flood Modeller Pro software. The schematisation and approach to model development is summarised in the following paragraphs.

3.1.1 1D Model Development

A new 1D (Flood Modeller) hydraulic model has been developed to represent the River Elwy study area using the 2020 survey data and Flood Modeller networks as outlined in Table 1-2.

Hydraulic structures have been added to the model based on the survey data provided. Where there are large stretches of un-surveyed river reach, interpolates have been added between surveyed sections for model stability. Manning's roughness coefficients (n)[2] were set using evidence from site visit photos.

Flood modeller Spill Units were used to represent bridge decks/parapets in Llanfair, to represent flow overtopping these structures. Weir coefficients were set to 1.5 for these spill units. Weirs were also represented using Spill Units, which allow the irregular profile of the weir crests to be represented. Weir coefficients were set to 1.5, assessed based on site photographs and values obtained from previous models.

Model cross sections have been deactivated at bank top in order to link with the 2D domain used to represent the floodplain. The upstream and downstream boundaries were set up as described in Section 3.3.

Once the above steps had been completed, initial conditions were created, and the model tested for a range of scenarios.

3.1.2 2D Model Development

A TUFLOW 2D domain has been created to represent floodplain areas adjacent to the River Elwy. This is linked to the 1D Flood Modeller reaches by 1D-2D internal (HX) boundaries. Ground levels in the 2D model have been set using the 2019 DTM LIDAR composite and 2D hydraulic roughness values are linked to OS mapping feature codes and set based on published values and previous examples as shown in Table 3-1. Flood defences around the urban area were added using 2D z lines to set their elevation. This model setup is demonstrated by Figure 3-1. Where OS mapping is not present within the 2D code, the material number was set to 5 (grass), which has been assessed as representative of the land use in these areas based on aerial photography.

Table 3-1 Land use type and associated Manning's n coefficient in the 2D model

Land use	Material number	Manning's n coefficient
Road	1	0.02
Water	2	0.035
Buildings	3	0.8
General surface	4	0.05
Grass	5	0.05
Conifer trees	6	0.1
Pavement	7	0.02

[2] Chow (1959). Manning's n Values. Available at: http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

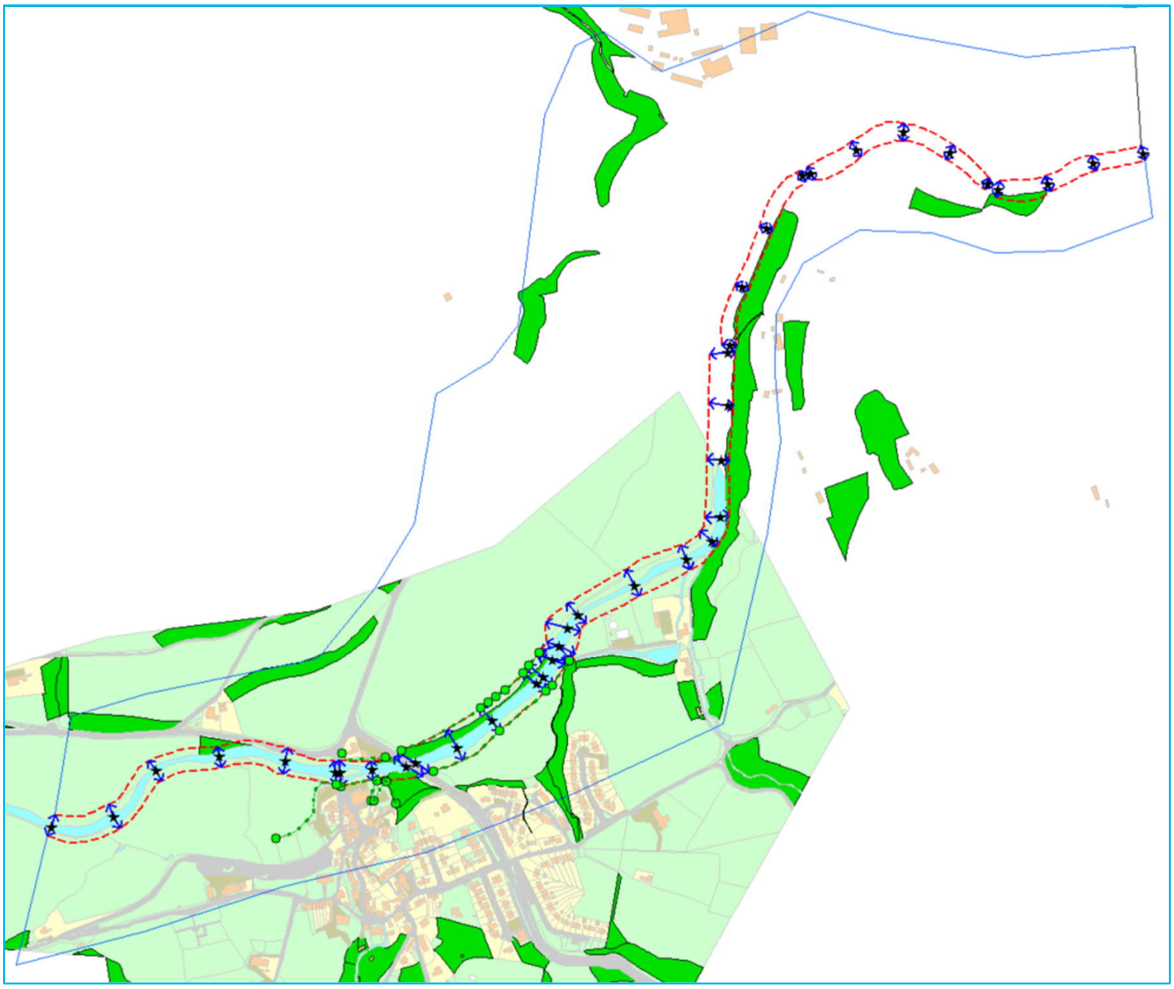


Figure 3-1 TUFLOW Model setup

3.1.3 Baseline Model

The baseline model is represented in Flood Modeller as shown in Figure 3-2. Interpolates added between the surveyed sections for model stability are shown. The sections labelled in the figure have been used to report results in Section 5.

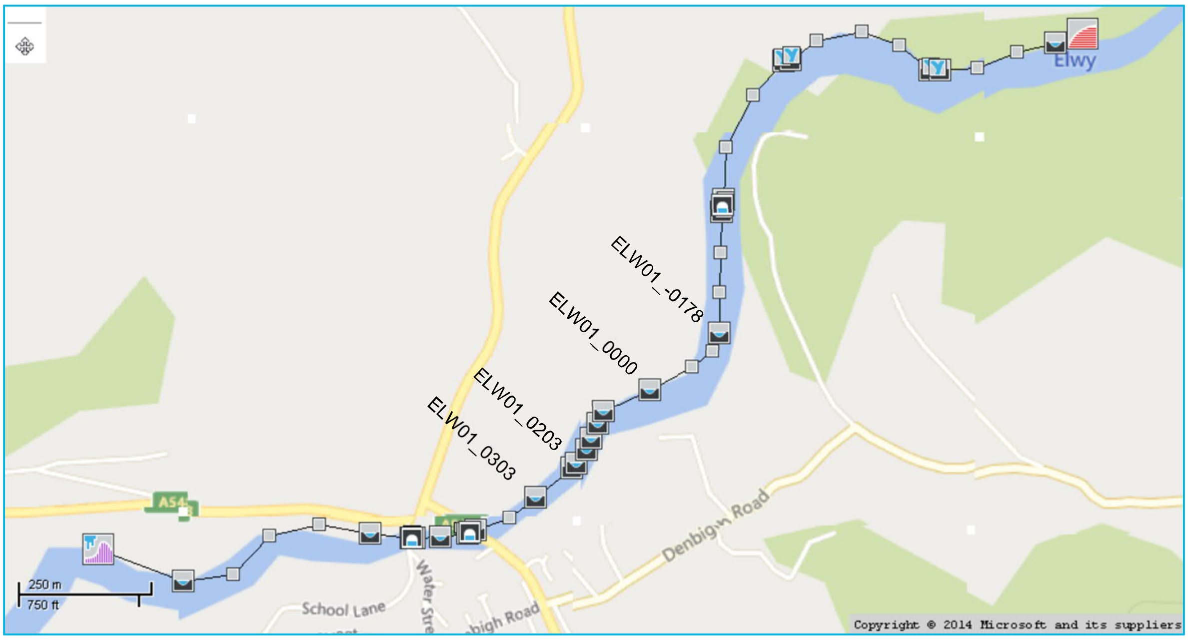


Figure 3-2 Baseline model development in Flood Modeller

3.1.4 Weir Removal Scenario

Model Set-up

The first scenario model was created to investigate the impact of weir removal on velocity in the channel. The weir removal was modelled by removing the spill unit representing the weir from the 1D model and re-grading the channel bed from the A544 bridge crossing (ELW01_0435) to 150m downstream of the weir (ELW01_0000) as shown in Figure 3-3 in comparison to the baseline channel bed. In all other respects, the Weir Removal Scenario model was unchanged from the baseline model.

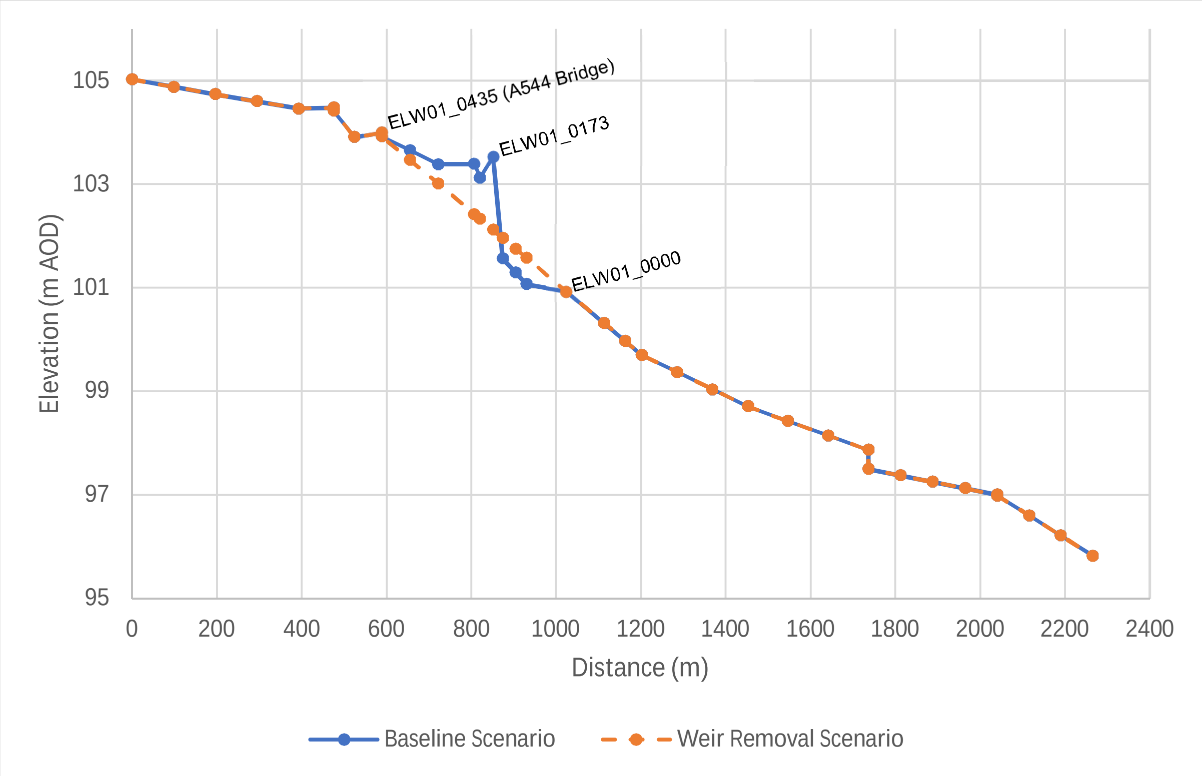


Figure 3-3 Channel bed long section for weir removal scenario in comparison to the baseline

Results

Removal of the weir and regrading of the channel was found to cause lowering of water levels upstream of the weir location and consequently less flow leaving the channel and entering the floodplain. This resulted in increased flows and velocities in the reaches upstream and downstream of the weir location. Further details are presented in Section 5.

3.1.5 Mitigation Scenarios

Since the Weir Removal Scenario was found to predict increased flow and velocity in the channel, with the potential to increase erosive potential, three mitigation options were considered. These aimed to reduce the velocity in the channel, with the aim of restoring the peak velocities predicted in the Baseline Scenario. The options were tested at a high level and would require further optimisation before considering implementation. It is assumed that by reducing the velocity in the channel, the potential for negative impacts on geomorphology and biodiversity will also be reduced.

The mitigation options were combined into two scenarios with both using the same intervention upstream of the weir location and differing approaches downstream.

Mitigation Scenario 1 introduced of a two-stage channel in the 1D model upstream of the weir (between the A544 bridge and the current location of the weir). Figure 3-4 shows an example model cross section including the two-stage channel together with the Baseline Scenario cross section and the re-graded channel cross section in the Weir Removal Scenario. In addition, a 40m wide strip of land, on the left bank downstream of the weir location was lowered in this scenario (Figure 3-5), to allow more water onto the floodplain and encourage flow in paleochannels (visible in Figure 1-4). To a achieve this, the bank downstream of the weir location was lowered to 102.7m AOD in the 2D model domain.

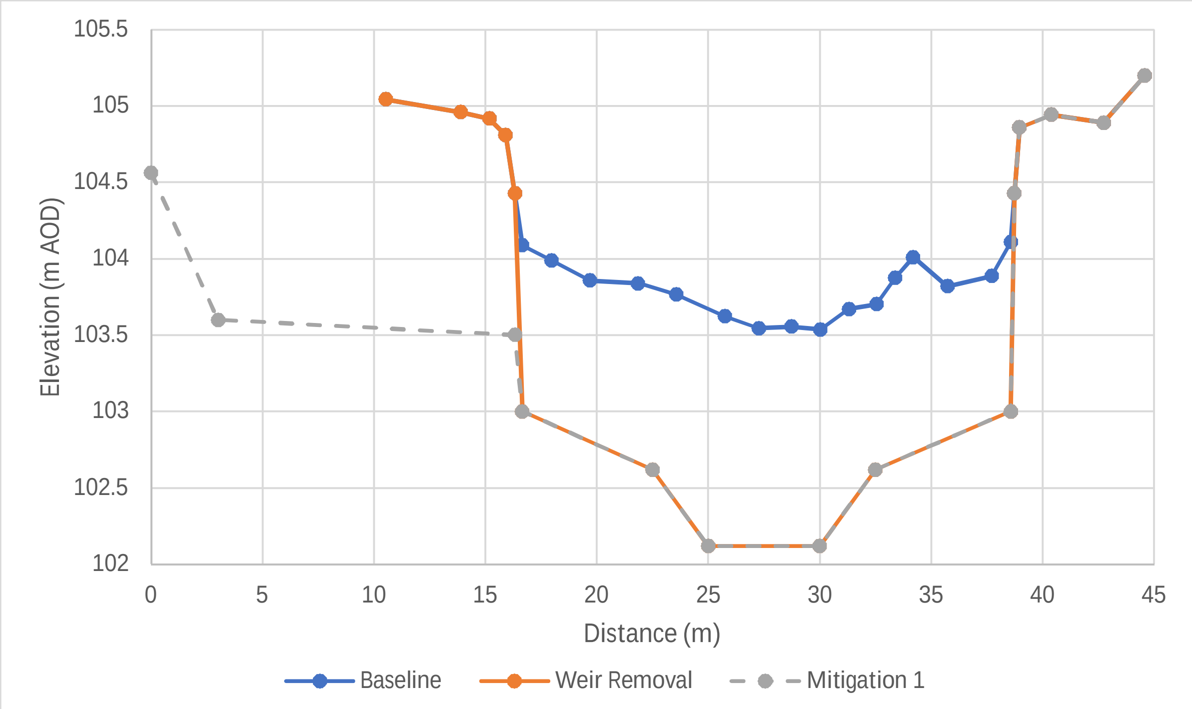


Figure 3-4 Cross section data changes made in Mitigation Scenario 1 upstream of the weir at ELW01_0173

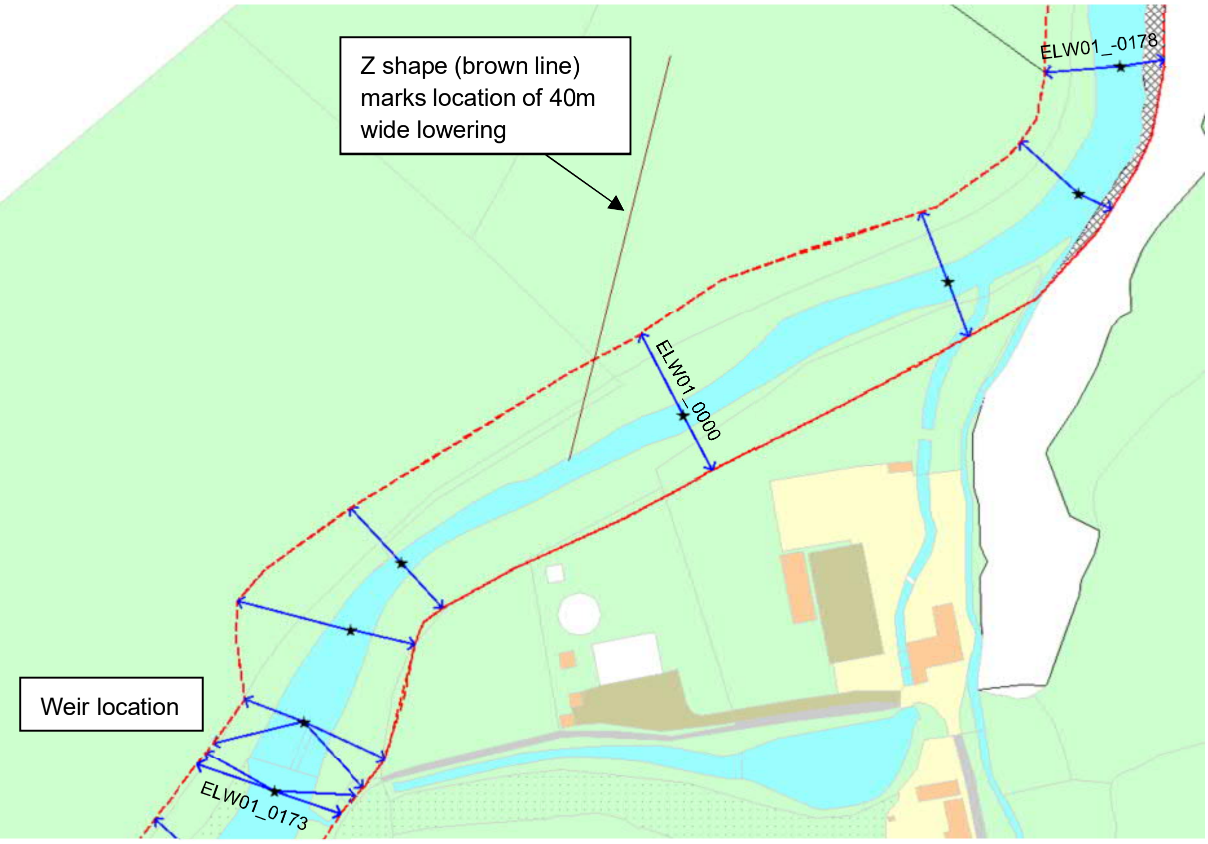


Figure 3-5 Location of bank lowering to 102.7m AOD downstream of the weir using a 2D z shape.

Mitigation Scenario 2 includes the two-stage channel upstream of the weir as in Mitigation Scenario 1; however, a two-stage channel is also introduced downstream of the current weir location as an alternative to the ground lowering in the 2D domain. An example of the changes is demonstrated in Figure 3-6.

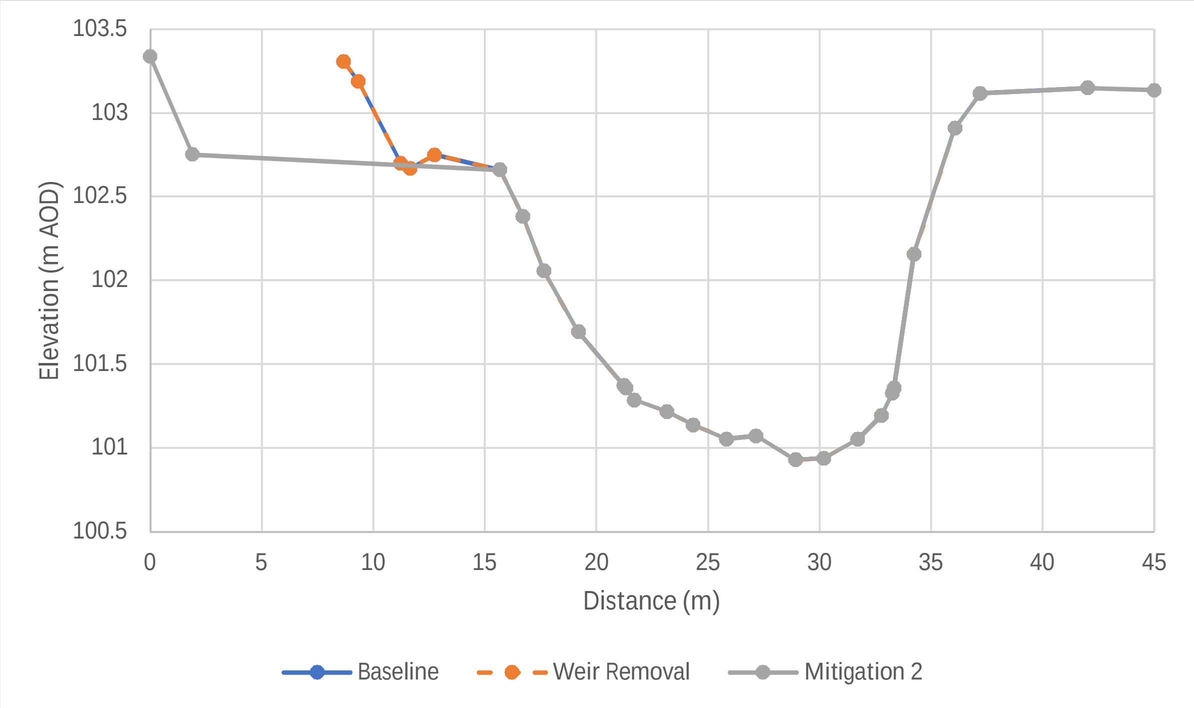


Figure 3-6 Cross section data demonstrating changes made for Mitigation Scenario 2 downstream of the weir at ELW01_0000

3.2 Model Structure and Naming Convention

Model files are organised within a standard folder structure as shown in Table 3-2. Model nodes names are retained as from the topographic survey.

Table 3-2: Flood Modeller folder structure

Folder	Sub-Folder	Contents
Flood Modeller	dat	Flood Modeller data files (dat)
	ief	Flood Modeller simulation files (ief)
	ied	Flood modeller event files (ied)
	results	Flood modeller results files (zzn, zzl, zzd etc.)
TUFLOW	checks	TUFLOW check files
	bc_dbase	TUFLOW boundary conditions
	model	TUFLOW boundary control file (tbc) and geometry control file (tgc), ground model (i.e. LIDAR DTM) and all GIS layers forming part of the TUFLOW model
	runs	TUFLOW control files (tcf), log files (tlf) and diagnostic messages files
	results	TUFLOW results files (2dm, dat, asc or tlf, mass balance, csv etc.)

3.3 Model Boundaries

This section should be read in conjunction with Section 2.

3.3.1 Upstream Boundary

The inflow was applied to the 1D model as a direct inflow at the first section in the model using a REFH Boundary in Flood Modeller to generate an inflow hydrograph. This was scaled to give the peak flow shown in Table 2-1 for each modelled event.

3.3.2 Downstream Boundary

The downstream boundary of the 1D domain was applied at the last section in the model as a Flood Modeller Normal-Depth boundary. The slope value for the boundary is calculated based on the average gradient in the 225m channel reach immediately upstream of the boundary. For the 2D domain, a TUFLOW HQ boundary was applied at the downstream end of the 2D domain, based on a slope of 1/400, assessed from LIDAR data.

3.4 Model Outputs

The models were set up to generate the following outputs:

- Flood Modeller unsteady 1D output files (zzl, zzn, zzd etc). Results were generated by the model at 300 second intervals.
- TUFLOW map outputs (xmdf format) including depth (d), water level (h), velocity (v), unit flow (q) and hazard (ZUK0). Map outputs were generated at 15-minute intervals, to allow the results to be animated while keeping results files to a manageable size.
- TUFLOW grid outputs (ASCII format) generated for peak depth, water level, velocity, unit flow and hazard.
- TUFLOW mass balance output and other standard diagnostic and log files.

4 Model Runs

The following scenarios were modelled in Flood Modeller (Table 4-1).

Table 4-1 Modelling scenarios in Flood Modeller

Modelling Scenario	Flood Modeller file (.dat)	TUFLOW files (tcf)	Description
Baseline	ELW01_FMP_004.dat	LlanfairTH_Elwy_~e~_004.tcf	Baseline model scenario including weir in current state.
Weir Removal	ELW01_FMP_WR_002.dat	LlanfairTH_Elwy_WR_~e~_002.tcf	Weir removal scenario with bed re-grading to A544 bridge.
Mitigation 1	ELW01_FMP_MIT_001.dat	LlanfairTH_Elwy_MIT_~e~_002.tcf	Introduction of two-stage channel upstream of weir location and lowering of left bank downstream.
Mitigation 2	ELW01_FMP_MIT_003.dat	LlanfairTH_Elwy_MIT_~e~_003.tcf	Introduction of two-stage channel upstream and downstream of weir.

4.1 Design Events

Each scenario was run with a suite of design events as follows; 1%, 2% and 10% AEP. The runs were carried out in unsteady state for a duration of 20 hours.

4.1.1 Storm Duration & Seasonality

The design storm duration used was the recommended duration from ReFH2 catchment descriptors. This is 7.5 hours. Detailed hydrological analysis of storm duration has not been deemed necessary for this study. This is because the assessment has considered the hydraulic changes caused by a physical change to the channel and therefore hydrology is not a key factor being considered. The appropriate seasonality for the design storm profile is 'Winter'.

5 Results

5.1 Impact on Velocity

Table 5-1 demonstrates the impact of weir removal and the two mitigation scenarios on peak velocity relative to the baseline throughout the modelled reach. It is evident that the largest impact on peak velocity is upstream of the current weir location, particularly at the location closest to the weir location; here, the channel gradient will increase most significantly following weir removal. It is also clear that the largest changes in velocity, compared to baseline, occur during the 10% AEP event. There is no notable difference between peak flows when comparing the two mitigation scenarios.

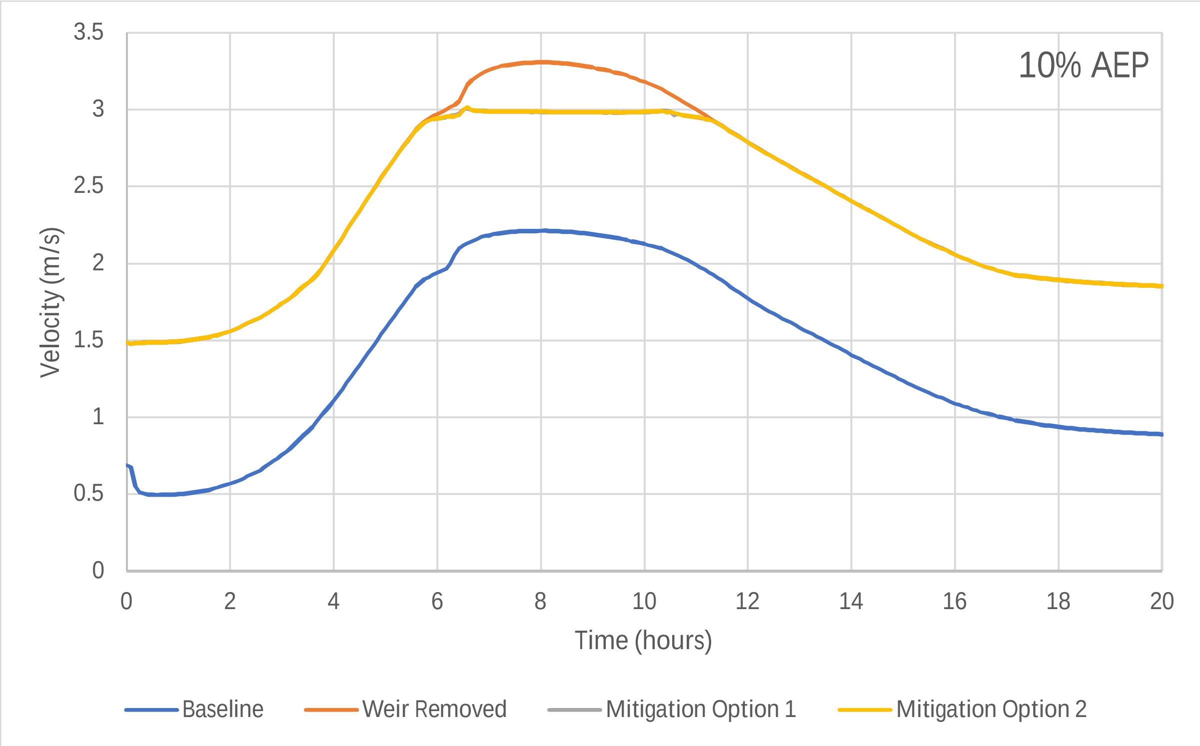
The four locations reported on are shown in Figure 3-2.

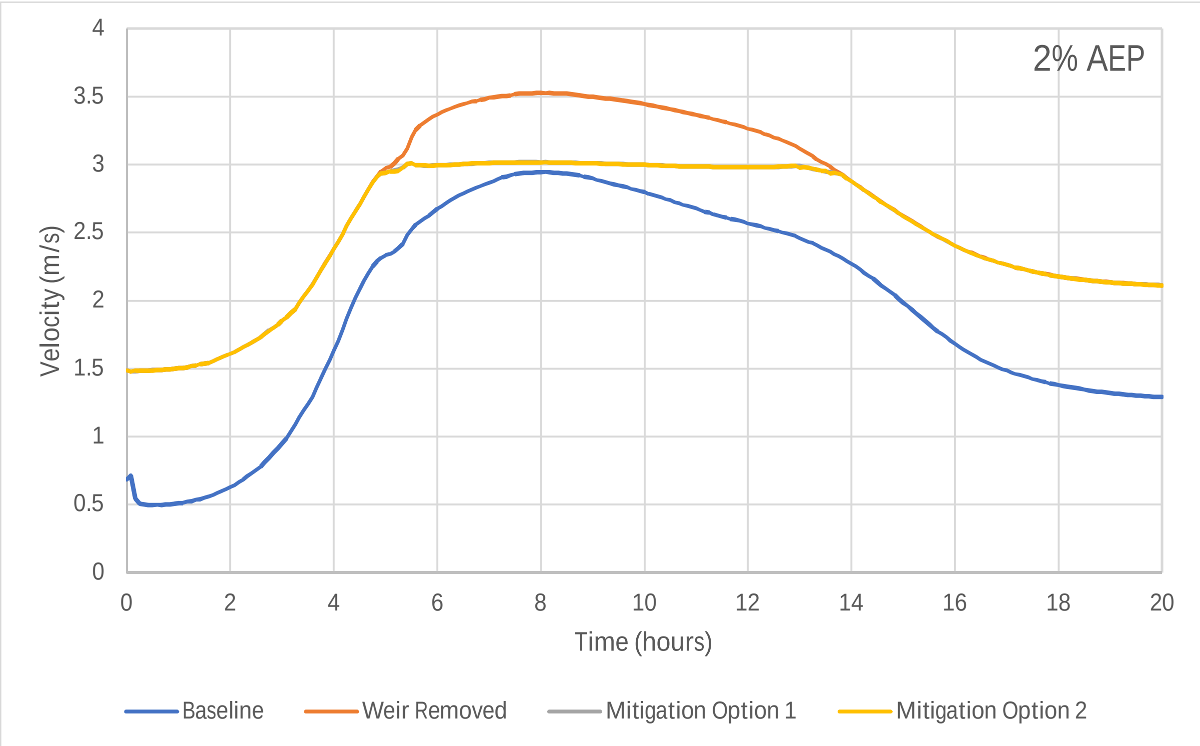
Table 5-1 Impact of weir removal and mitigation scenarios on velocity

Location	Modelled Scenario	Velocity (m/s)			Proportion of baseline (%)		
		10% AEP	2% AEP	1% AEP	10% AEP	2% AEP	1% AEP
ELW01_0303 (130m u/s of weir)	Baseline	2.21	2.95	3.10			
	Weir Removal	3.31	3.53	3.60	149%	120%	116%
	Mitigation 1	3.01	3.02	3.03	136%	102%	98%
	Mitigation 2	3.02	3.02	3.03	136%	102%	98%
ELW01_0203 (30m u/s of weir)	Baseline	1.46	2.11	2.28			
	Weir Removal	2.93	3.07	3.11	201%	146%	137%
	Mitigation 1	2.76	2.80	2.81	190%	133%	123%
	Mitigation 2	2.79	2.81	2.82	192%	133%	124%
ELW01_0000 (166m d/s of weir)	Baseline	1.96	1.93	1.94			
	Weir Removal	1.97	2.03	2.16	100%	105%	112%
	Mitigation 1	1.95	1.96	2.01	99%	101%	104%
	Mitigation 2	2.00	1.97	1.99	102%	102%	103%
ELW01_-0178 (344m d/s of weir)	Baseline	2.10	2.06	2.06			
	Weir Removal	2.13	2.14	2.15	101%	104%	104%
	Mitigation 1	2.12	2.13	2.14	101%	103%	103%
	Mitigation 2	2.04	2.11	2.12	97%	102%	103%

The below figures present timeseries demonstrating the impact of each of the modelled scenarios on in-channel velocity in comparison to the baseline.

The graphs in Figure 5-1 demonstrate that 130m upstream of the weir (ELW01_0303), weir removal results in an increase in velocity. This is expected because the baseline velocities are in an area where the bed gradient is starting to flatten due to the weir, slightly impounding the flow. Mitigation Scenarios 1 and 2 decrease the velocity compared to that of that Weir Removal Scenario with the peak appearing to plateau, demonstrating the impact of the two-stage channel. With the inclusion of mitigation, peak velocities remain above the baseline for the 10% AEP event, are approximately equivalent to the baseline for the 2% AEP event, and are slightly lower than the baseline for the 1% AEP event. It should also be noted that the peak velocity with mitigations is approximately 3 m/s for all events. The results suggest that the impact of the weir for the base case reduces as the size of the event increases. The results also suggest that the impact of the mitigations increases as the size of the event increases. The velocities shown by the model, even when mitigated, suggest that erosion may be an issue in this reach of the watercourse.


10% AEP
Velocity (m/s)
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
16
18
20
Time (hours)
Baseline
Weir Removed
Mitigation Option 1
Mitigation Option 2


2% AEP
Velocity (m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
16
18
20
Time (hours)
Baseline
Weir Removed
Mitigation Option 1
Mitigation Option 2

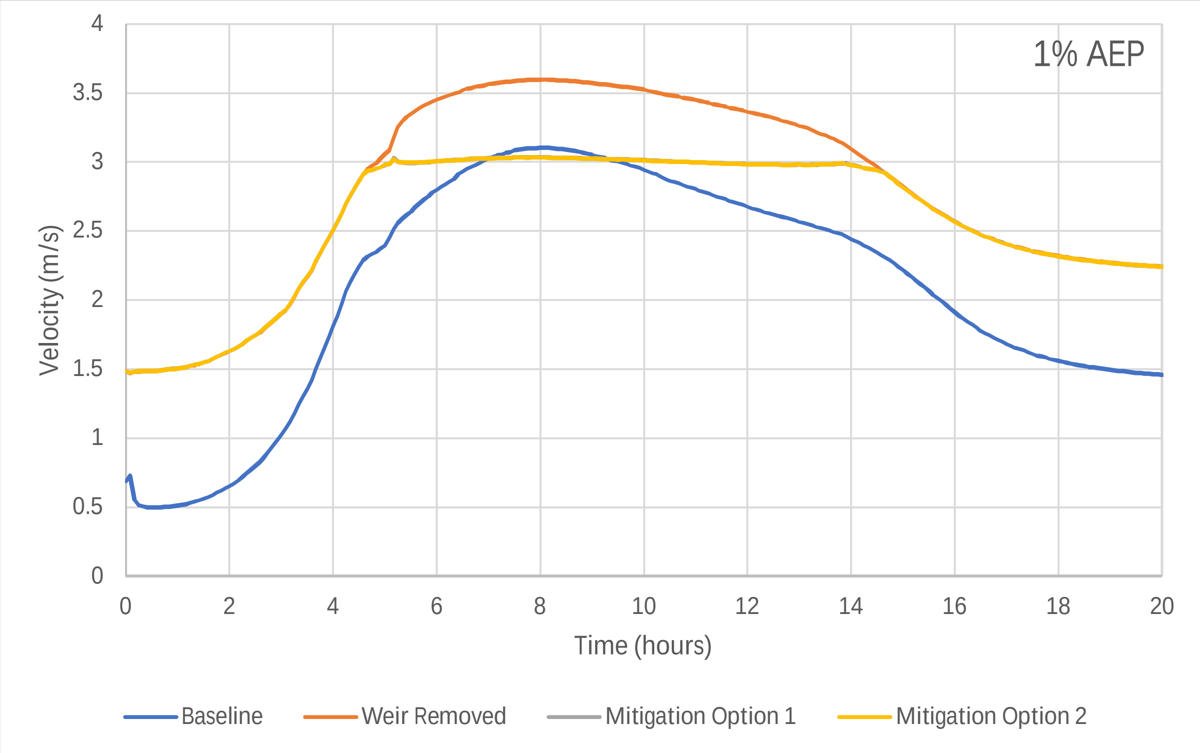
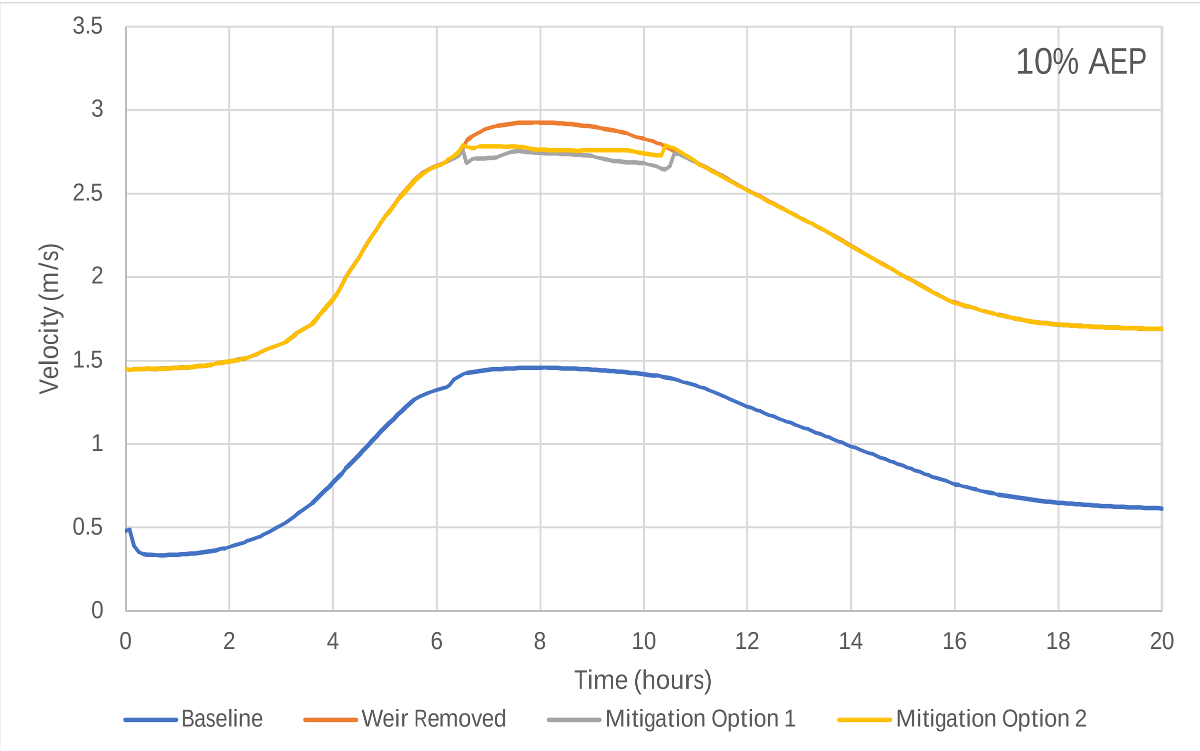


Figure 5-1 Velocity timeseries 130m upstream of the weir location (ELW01_0303)

The graphs in Figure 5-2 demonstrate that 30m upstream of the weir (ELW01_0203) weir removal results in a large increase in velocity. During the 10% AEP event, velocity doubles to 2.93m/s. This is expected because the existing channel at this location has a flat gradient and flows are impounded behind the weir, lowering velocities. When the weir is removed and the channel regraded, the flows are similar to those seen upstream. They are actually slightly lower and that is caused by a slight widening of the channel from 18m to 22m at the weir.

The mitigation causes a similar reduction in velocity to the upstream section, but this does not compare to the pre-weir velocities due to the large impact the structure has at this location. The velocities shown by the model, even when mitigated, suggest that erosion may be an issue in this reach of the watercourse.



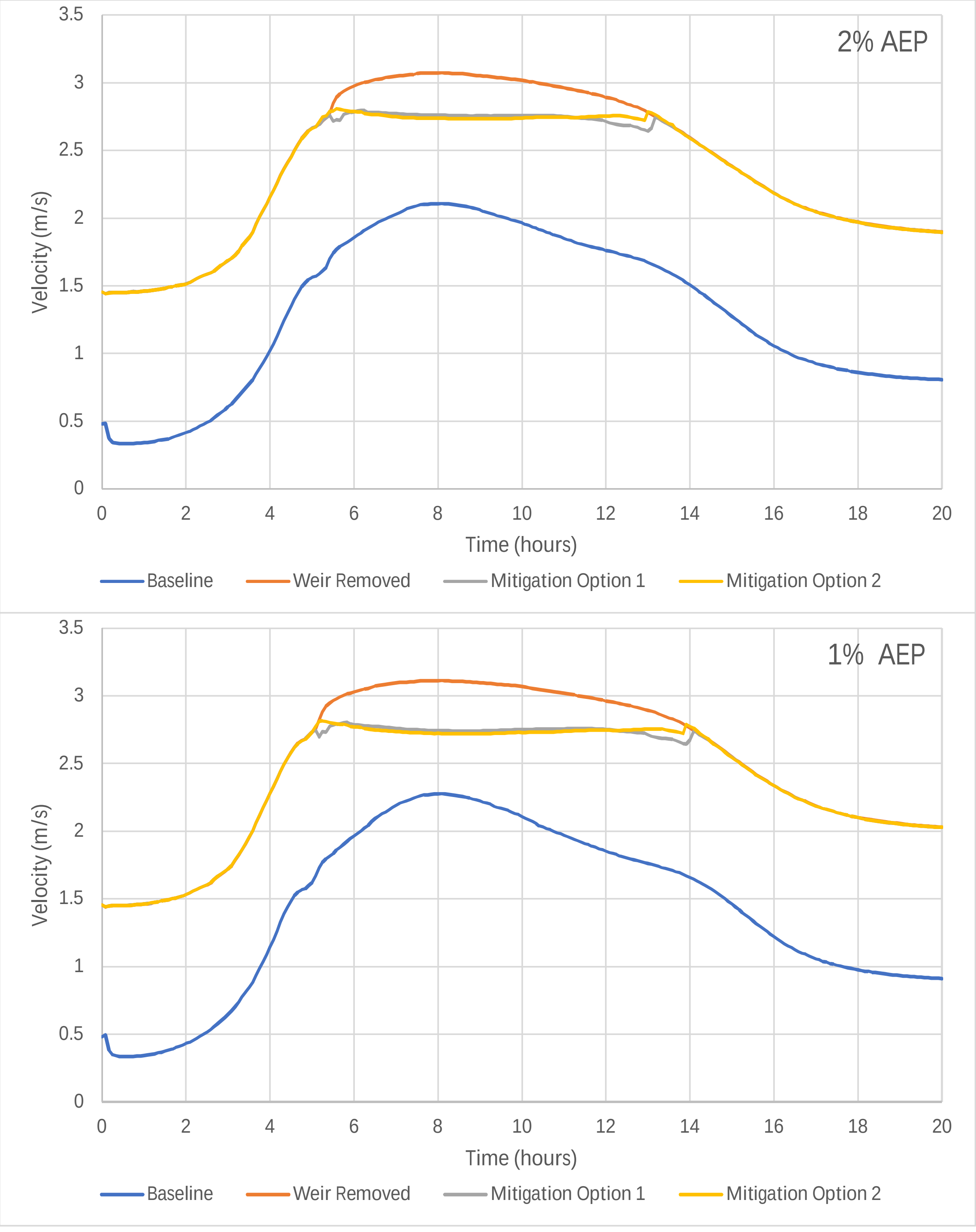
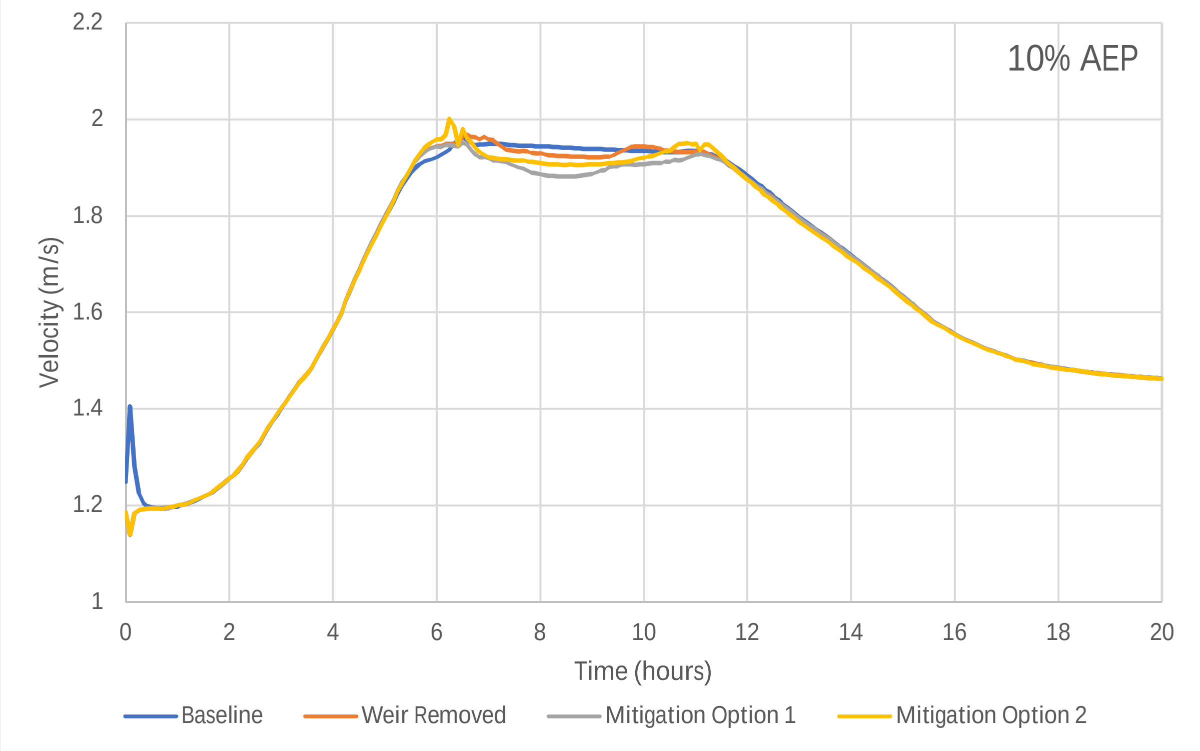


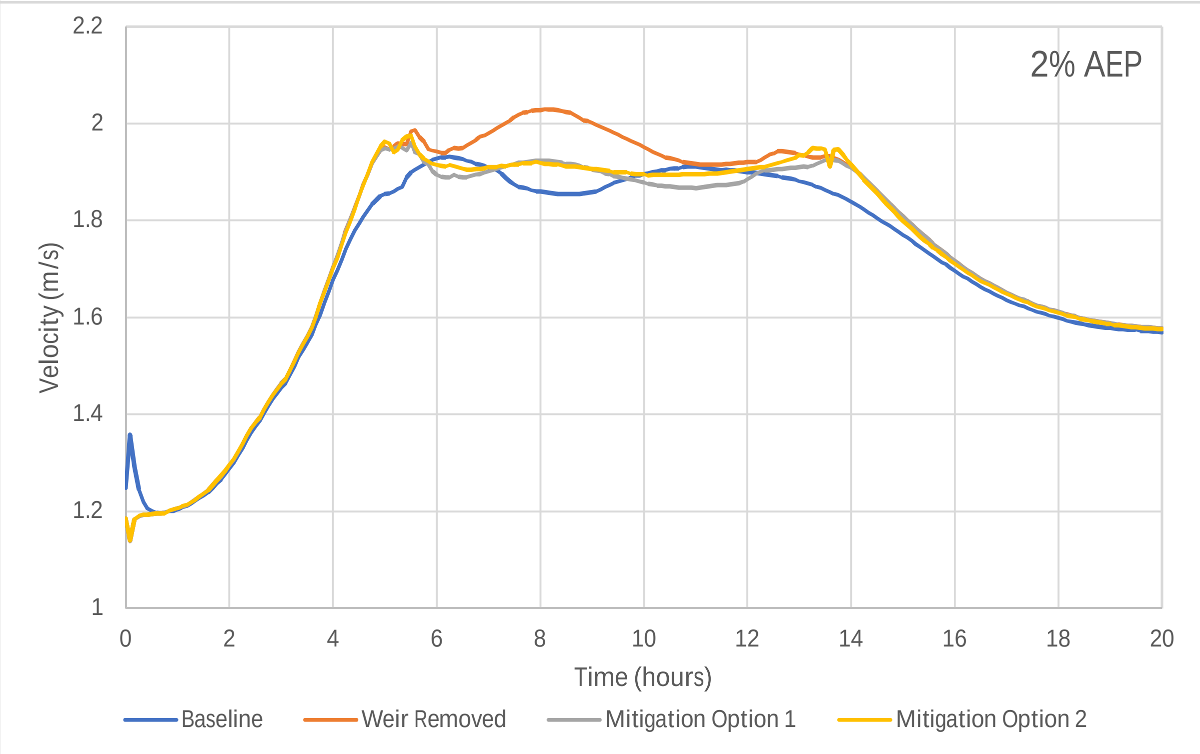
Figure 5-2 Velocity timeseries of the weir location 30m upstream of the weir location (ELW01_0203)

Figure 5-3 shows the impact of flow leaving the channel downstream of the weir. During the 10% event, there is little difference as the flows are similar and the mitigations have had little effect. The larger events show that the base case velocity has an early peak, a prolonged dip, and then has a second peak before the receding limb. When the weir is removed, the middle dip becomes a higher peak. This is because the lower water levels prevent water leaving the channel upstream of the weir; therefore, there is more flow in the channel causing velocities to increase.

Both mitigation approaches have a positive impact, broadly returning velocities to the pre-removal levels for all but the largest events.

It should be noted that the changes in velocity in this section are relatively minor with a maximum increase caused by the weir removal of under 0.5m/s during a 1% AEP event. The velocities may also not be sufficiently high to signify a significant erosion risk.





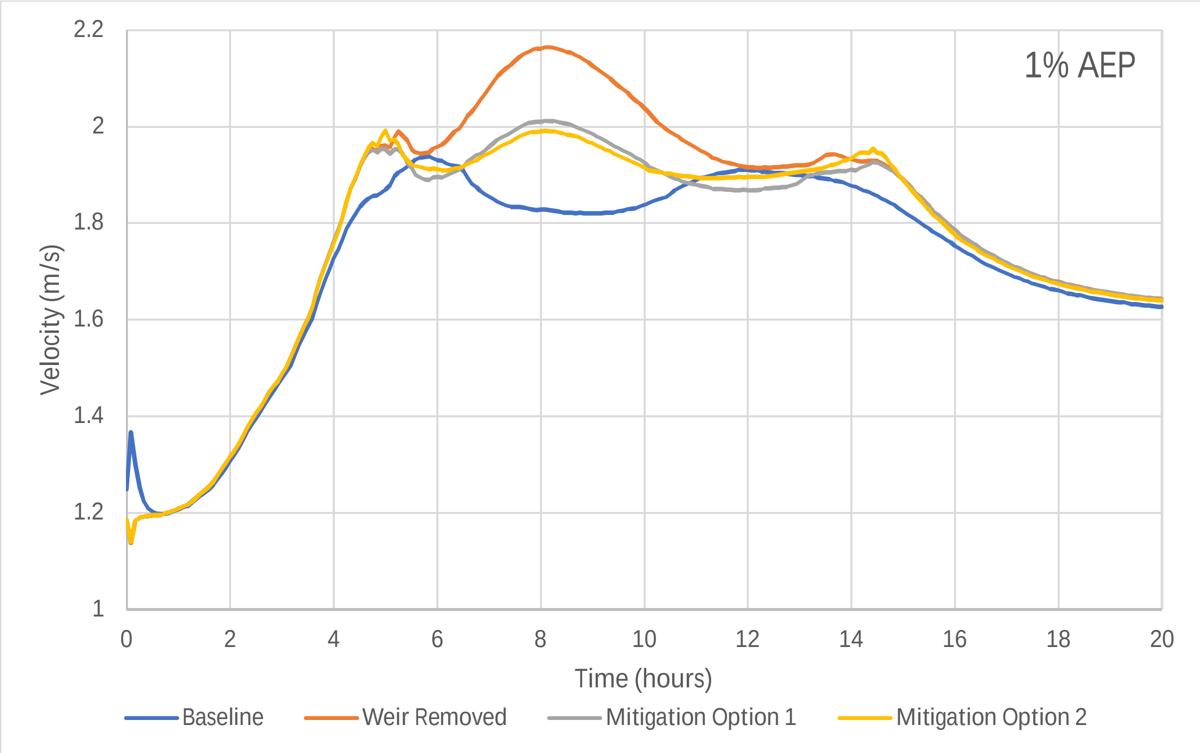
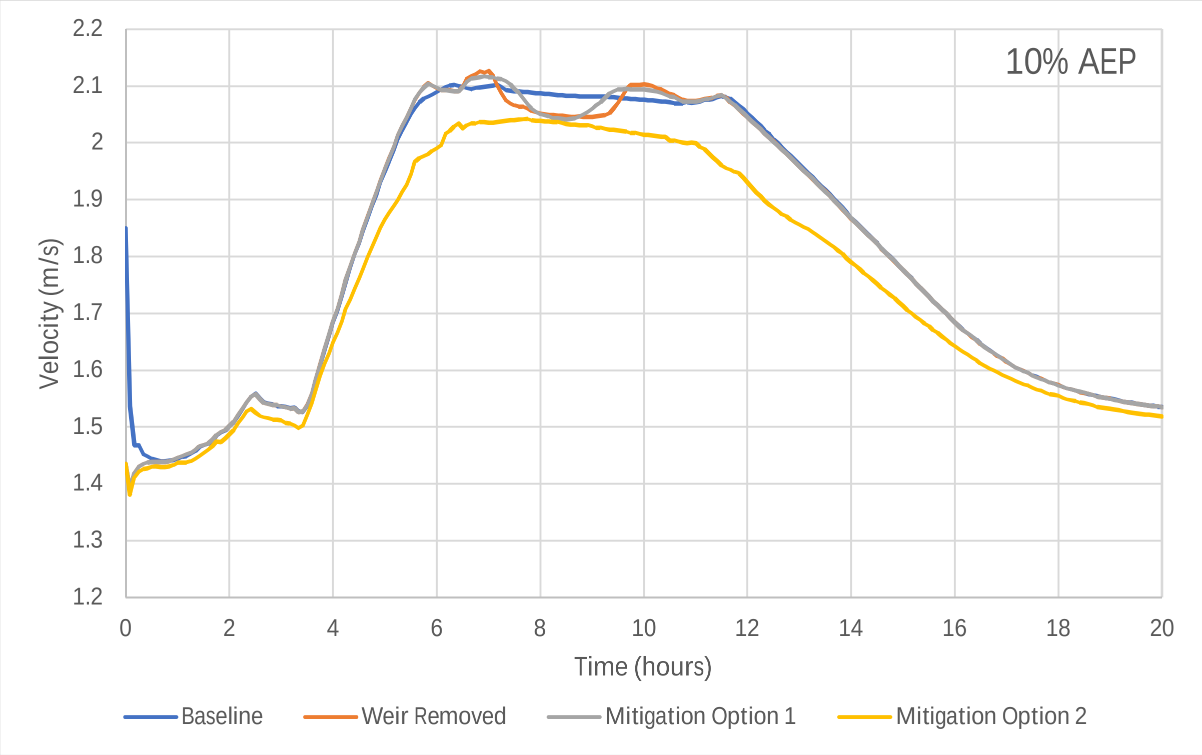


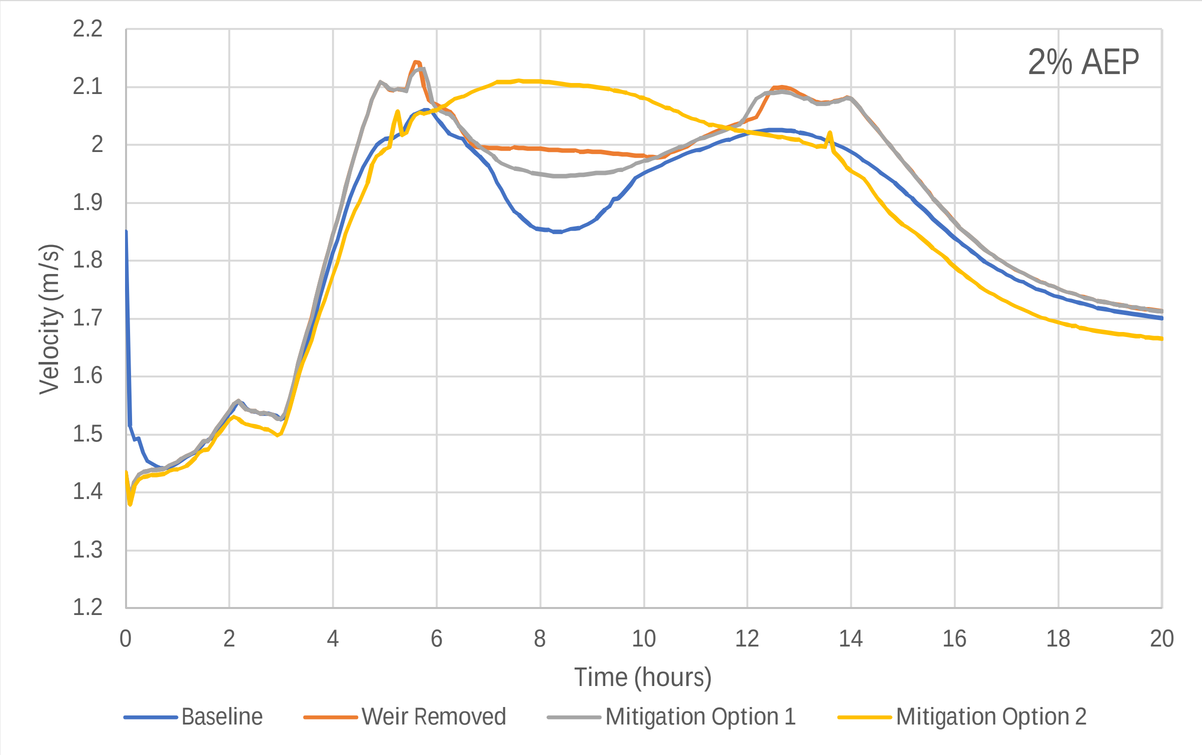
Figure 5-3 Velocity timeseries 166m downstream of the weir location (ELW01_0000)

Figure 5-4 shows that the base cases has a similar pattern further downstream from the weir, but with a more pronounced dip in the middle of the hydrograph. This suggests that flow leaving the channel upstream of the weir and re-entering the channel downstream of this location is impacting velocities during the peak of the event. In the weir removed case, less flow enters the floodplain upstream, resulting in slightly higher velocities and a reduced dip in velocity during the peak of the event.

The mitigation scenarios have very different impacts at this point in the downstream channel. The connection to the floodplain (scenario 1) provides a partial return to the base case flow pattern by allowing more flow to enter the floodplain. The two-stage channel (scenario 2) causes the velocity to behave very differently. The velocity graph is generally a simple bell curve shape with a peak higher than all other scenarios at high flow. This may suggest that the reduced water levels in the channel further reduce the flow entering the floodplain downstream of the weir and increase flow at this point in the channel. Further investigation would be needed to confirm that this is the case.

It should be noted that the changes in velocity demonstrated by the model are relatively minor and may not be sufficiently high to signify a significant erosion risk.


10% AEP
Velocity (m/s)
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
14
16
18
20
Time (hours)
Baseline
Weir Removed
Mitigation Option 1
Mitigation Option 2


2% AEP
Velocity (m/s)
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
2
4
6
8
10
12
14
16
18
20
Time (hours)
Baseline
Weir Removed
Mitigation Option 1
Mitigation Option 2

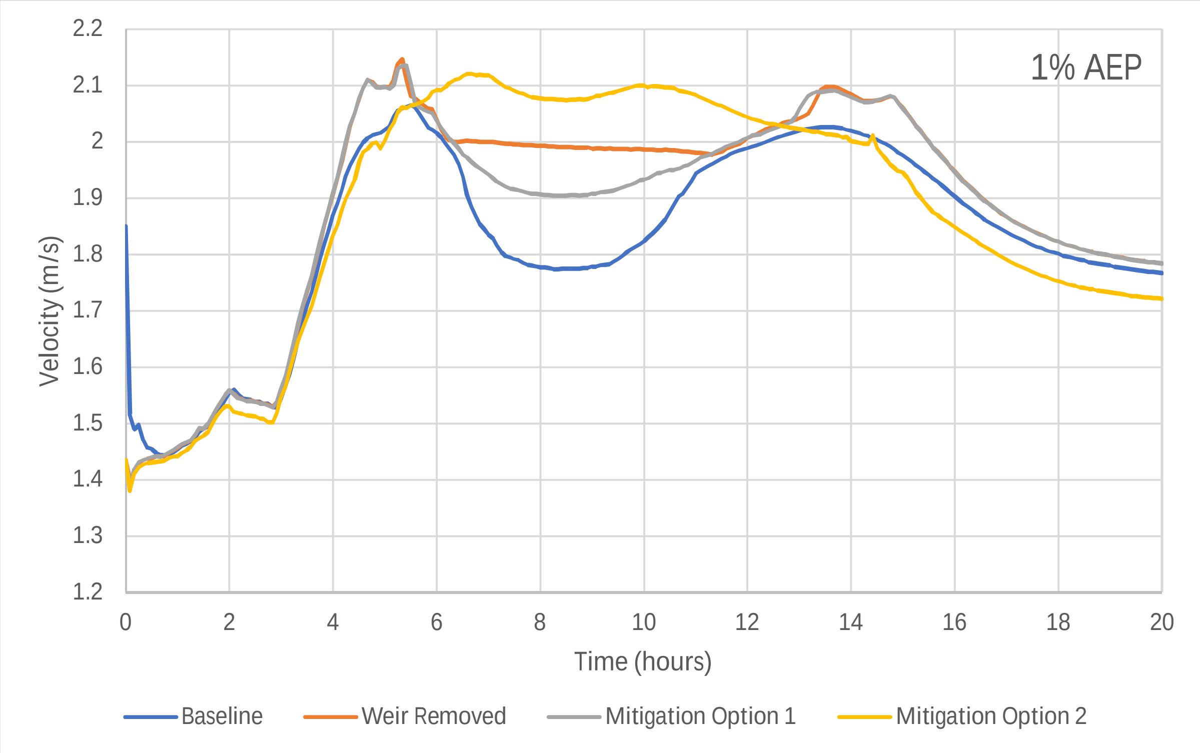
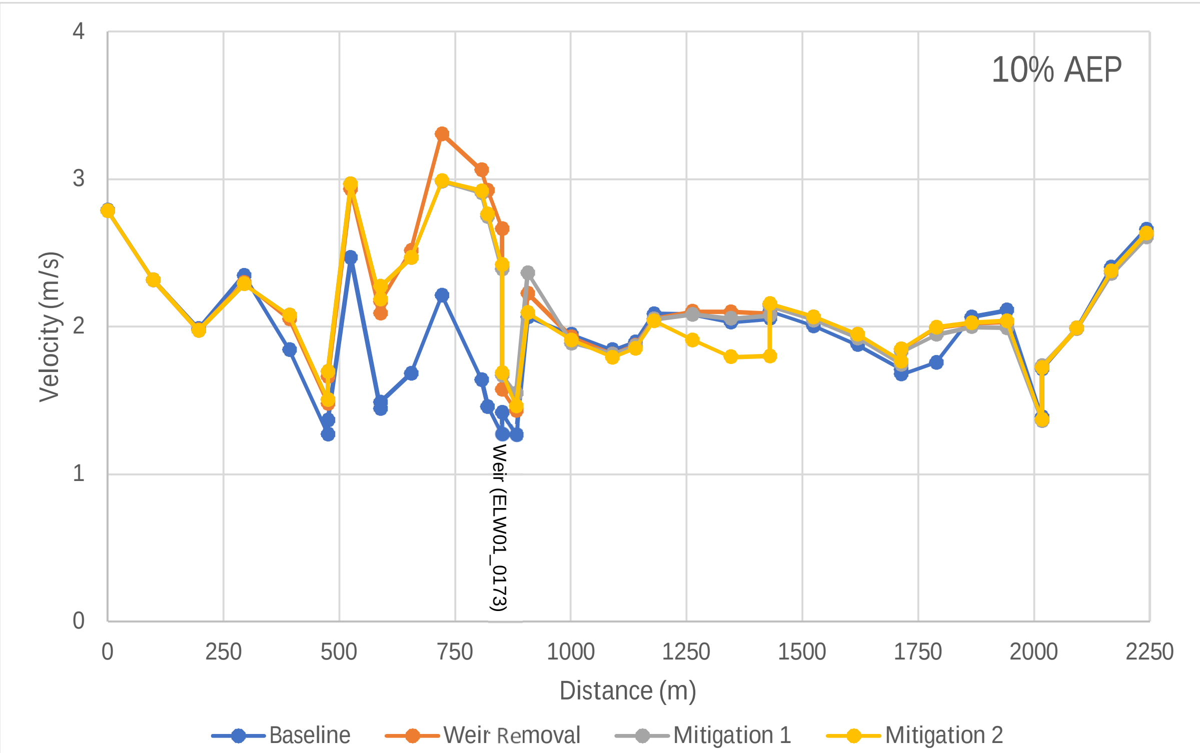


Figure 5-4 Velocity timeseries 344m downstream of the weir location (ELW01_-0178)

Figure 5-5 demonstrates the velocity profiles along the river reach during the peak of the event (at 8 hours) for each of the modelled scenarios. Velocity upstream of the weir location increases in all scenarios following weir removal. This is expected, as the slope has increased. For the first 1000m downstream of the weir location, in general velocity has increased slightly compared to the baseline, however not by a significant amount.



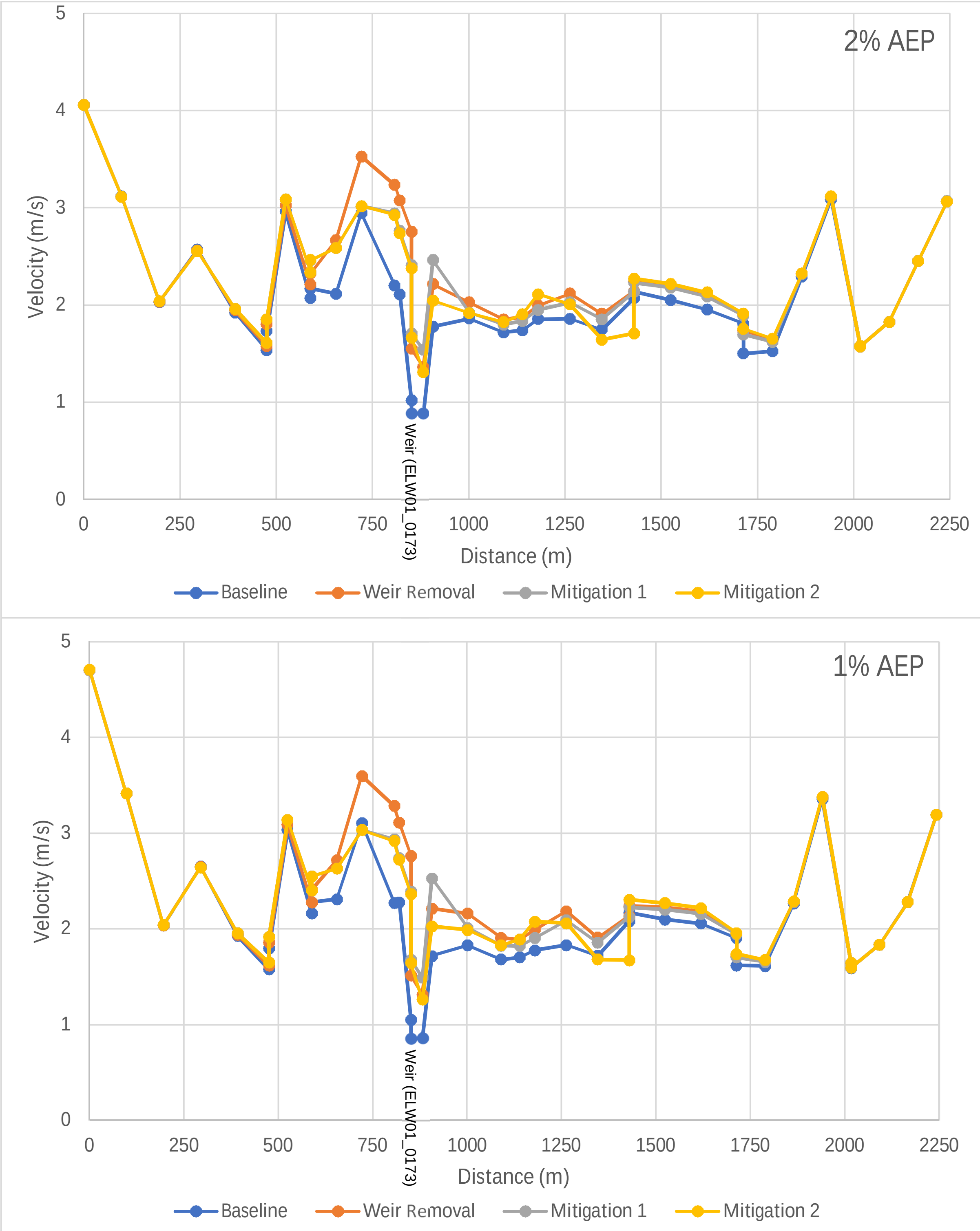


Figure 5-5 Velocity long profiles during the peak of the event along the modelled reach

5.2 Impact on Flow

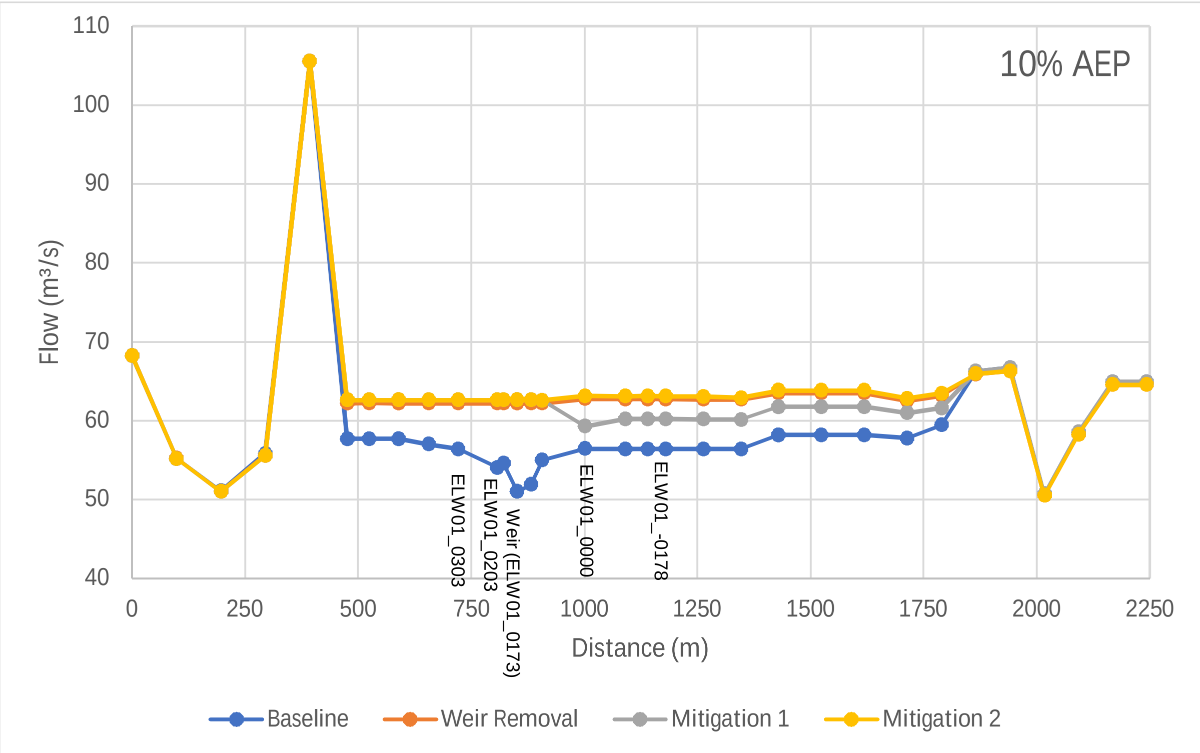
Table 5-2Table 5-2 demonstrates the in-channel peak flow though the modelled reach. In-channel peak flows vary between locations due to the exchange of water between the channel and floodplain.

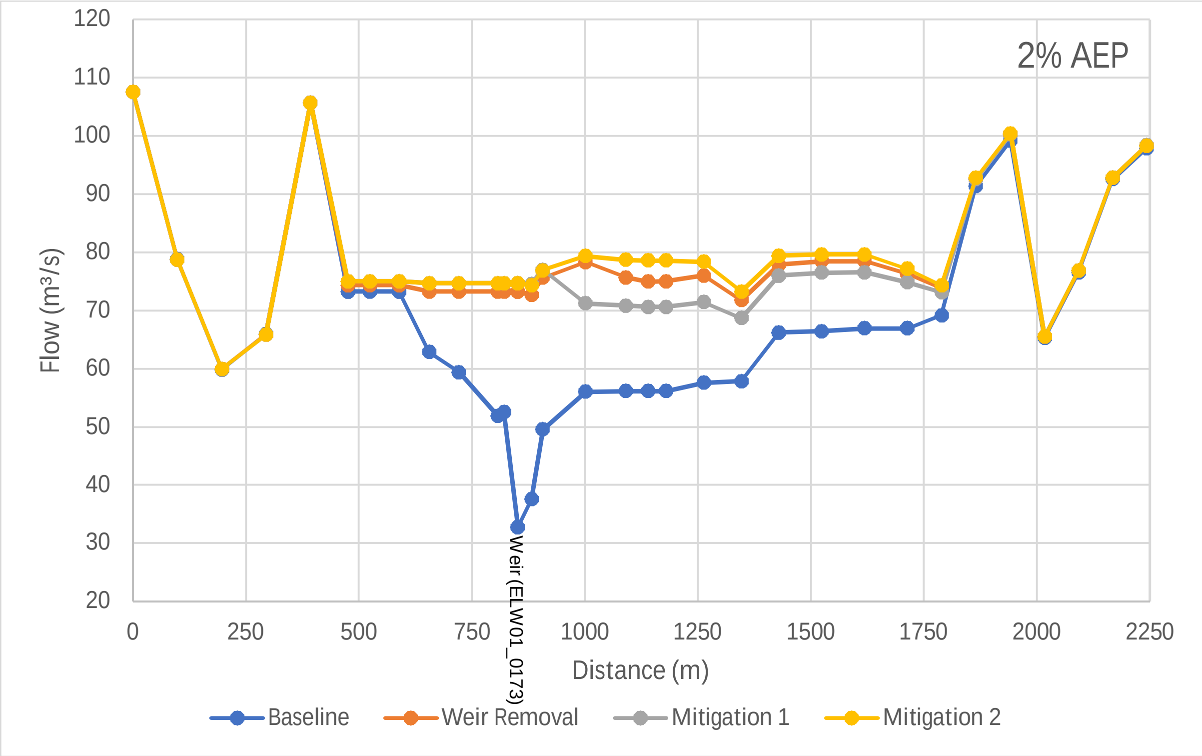
Weir removal results in an increase in flow in all modelled scenarios and events. This is due to a reduction in water level upstream of the weir location causing a reduction in the flow leaving the channel. Following weir removal, in channel flow is decreased the most by Mitigation Scenario 1 downstream of the weir location. This is due to the flow being diverted out of the channel by the left bank lowering in this scenario. The impact of this bank lowering on peak flow is evident for approximately 750m downstream (Figure 5-3).

The impact of Mitigation Scenario 2 is to further increase the in-channel flow downstream of the weir location, over that in the weir removal scenario. This is because the two-stage channel increases the channel capacity and hence lowers in-channel water levels, causing a further reduction in flow leaving the channel.

Table 5-2 Flow results

Location	Baseline	Weir Removal	Mitigation 1	Mitigation 2
Peak flow (m^3/s) 10% AEP Event				
ELW01_0303	56.40	62.21	62.60	62.60
ELW01_0203	54.62	62.21	62.60	62.61
ELW01_0173 (Weir)	51.00	62.22	62.60	62.60
ELW01_0000	56.43	62.75	59.30	63.12
ELW01_-0178	56.41	62.74	60.21	63.11
Peak flow (m^3/s) 2% AEP Event				
ELW01_0303	59.40	73.24	74.67	74.68
ELW01_0203	52.53	73.24	74.66	74.65
ELW01_0173 (Weir)	32.78	73.24	74.65	74.65
ELW01_0000	56.03	78.31	71.20	79.35
ELW01_-0178	56.14	74.97	70.57	78.59
Peak flow (m^3/s) 1% AEP Event				
ELW01_0303	64.33	77.14	79.09	79.09
ELW01_0203	56.37	77.14	79.10	79.09
ELW01_0173 (Weir)	34.86	77.13	79.09	79.08
ELW01_0000	62.35	87.05	78.39	88.25
ELW01_-0178	62.45	79.76	74.62	84.15





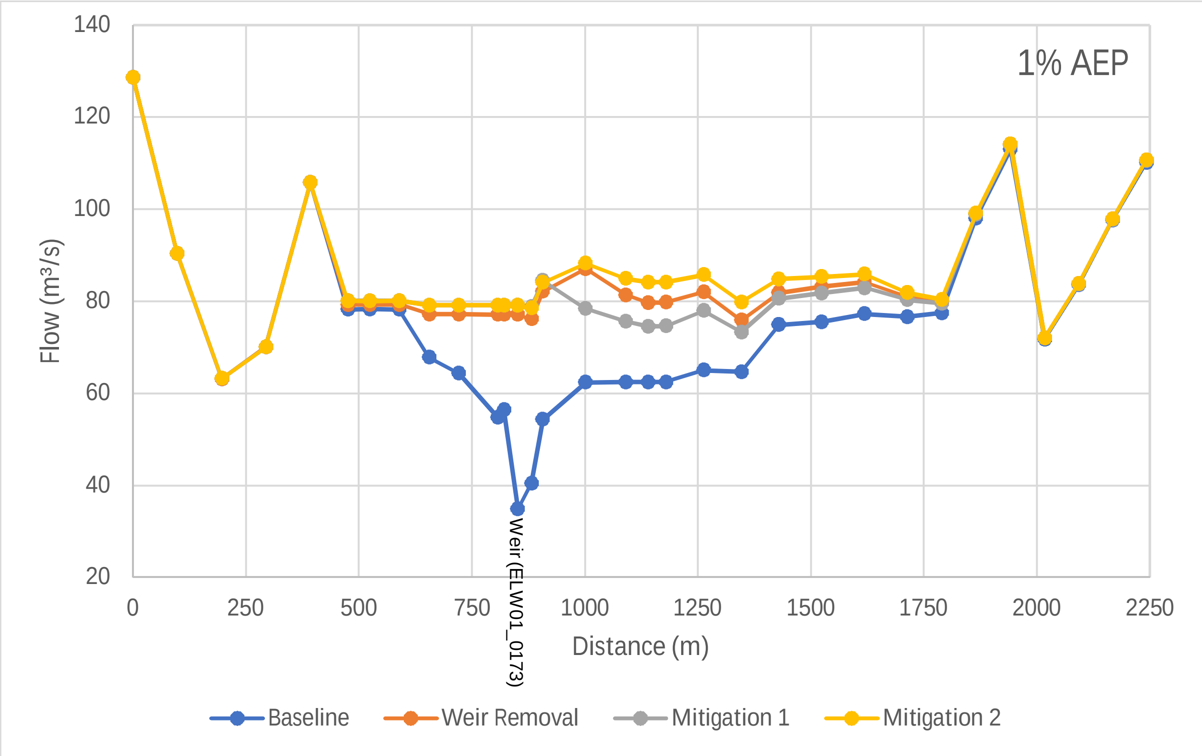


Figure 5-6 Flow long sections along the river reach for modelled scenarios

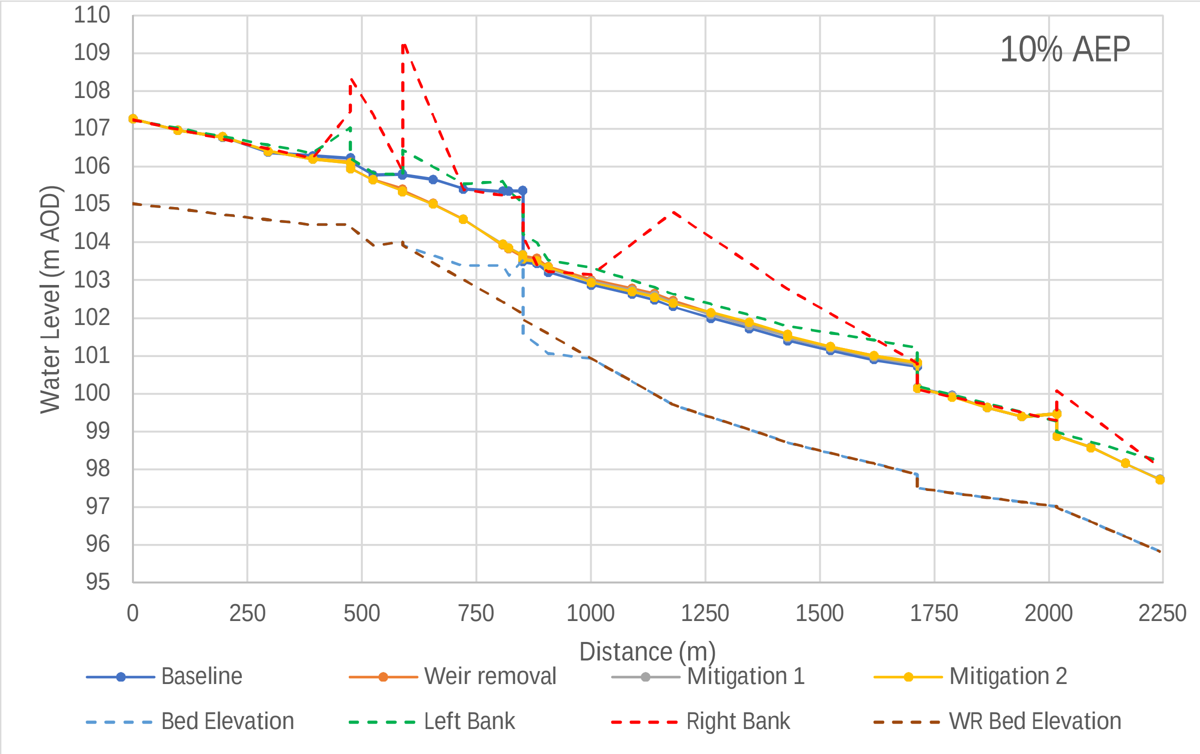
5.3 Water Level Impact

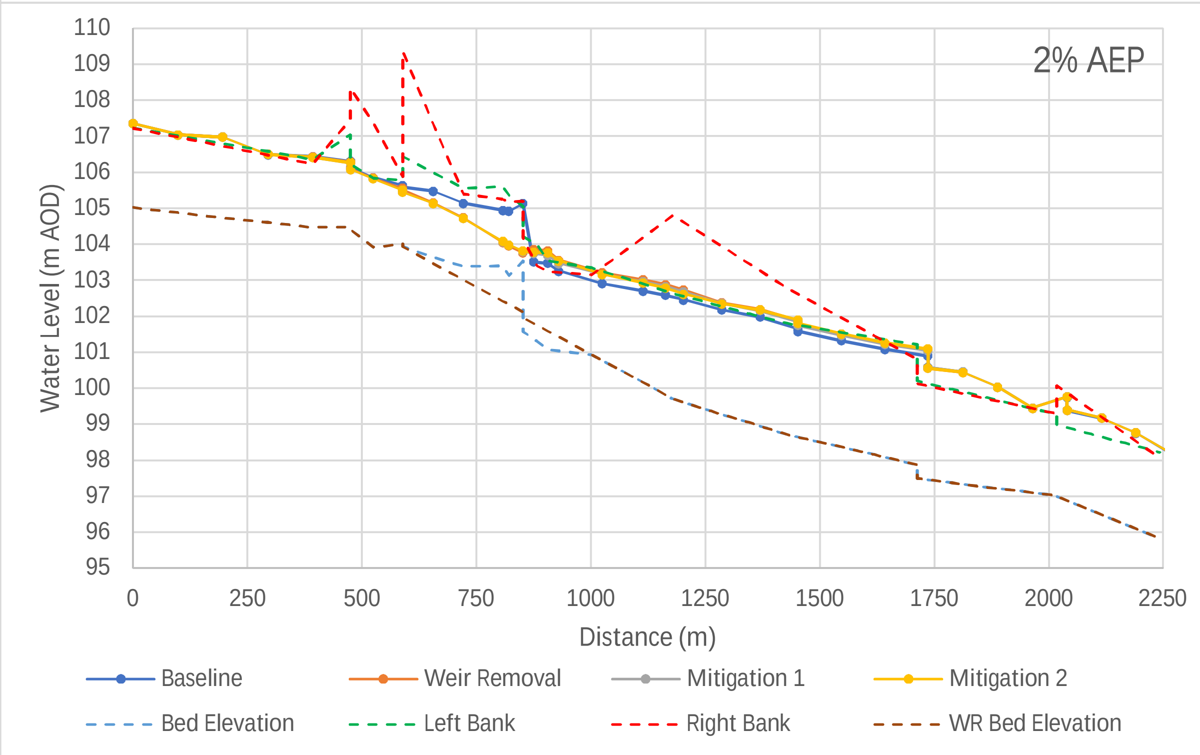
Figure 5-7**Error! Reference source not found.** and Table 5-3 demonstrate the impact of weir removal and mitigation scenarios on water level through the river reach. As expected, the largest decreases in water level are at the weir location and immediately upstream where the channel bed has been regraded following removal. Downstream of the weir, water levels have increased as the upstream water level drop has prevented flows from leaving the channel. The increases in water level are relatively minor at approximately 0.15m during the 10%

AEP event, 0.3m during the 2% AEP event and 0.2m during the 1% AEP event following weir removal. The lower difference for the 1% AEP event is because the downstream channel is able to connect with the floodplain which reduces the channel differences. Both mitigation scenarios have a very limited impact on reducing water level back to the baseline level downstream of the weir.

Table 5-3 Water level results

Location	Baseline	Weir Removal	Mitigation 1	Mitigation 2
Water Level (m AOD) 10% AEP Event				
ELW01_0303	105.41	104.61	104.60	104.60
ELW01_0203	105.36	103.82	103.85	103.85
ELW01_0173 (Weir)	105.37	103.61	103.67	103.66
ELW01_0000	102.86	103.00	102.96	102.94
ELW01_-0178	102.30	102.46	102.41	102.39
Water Level (m AOD) 2% AEP Event				
ELW01_0303	105.13	104.74	104.72	104.72
ELW01_0203	104.92	103.96	103.98	103.99
ELW01_0173 (Weir)	105.13	103.76	103.80	103.81
ELW01_0000	102.91	103.21	103.16	103.17
ELW01_-0178	102.45	102.73	102.68	102.62
Water Level (m AOD) 1% AEP Event				
ELW01_0303	105.17	104.78	104.76	104.76
ELW01_0203	104.91	104.00	104.03	104.04
ELW01_0173 (Weir)	105.16	103.82	103.86	103.87
ELW01_0000	103.06	103.26	103.22	103.24
ELW01_-0178	102.64	102.81	102.78	102.73


10% AEP
Water Level (m AOD)
110
109
108
107
106
105
104
103
102
101
100
99
98
97
96
95
0
250
500
750
1000
1250
1500
1750
2000
2250
Distance (m)
Baseline
Weir removal
Mitigation 1
Mitigation 2
Bed Elevation
Left Bank
Right Bank
WR Bed Elevation


2% AEP
Water Level (m AOD)
110
109
108
107
106
105
104
103
102
101
100
99
98
97
96
95
0
250
500
750
1000
1250
1500
1750
2000
2250
Distance (m)
Baseline
Weir Removal
Mitigation 1
Mitigation 2
Bed Elevation
Left Bank
Right Bank
WR Bed Elevation

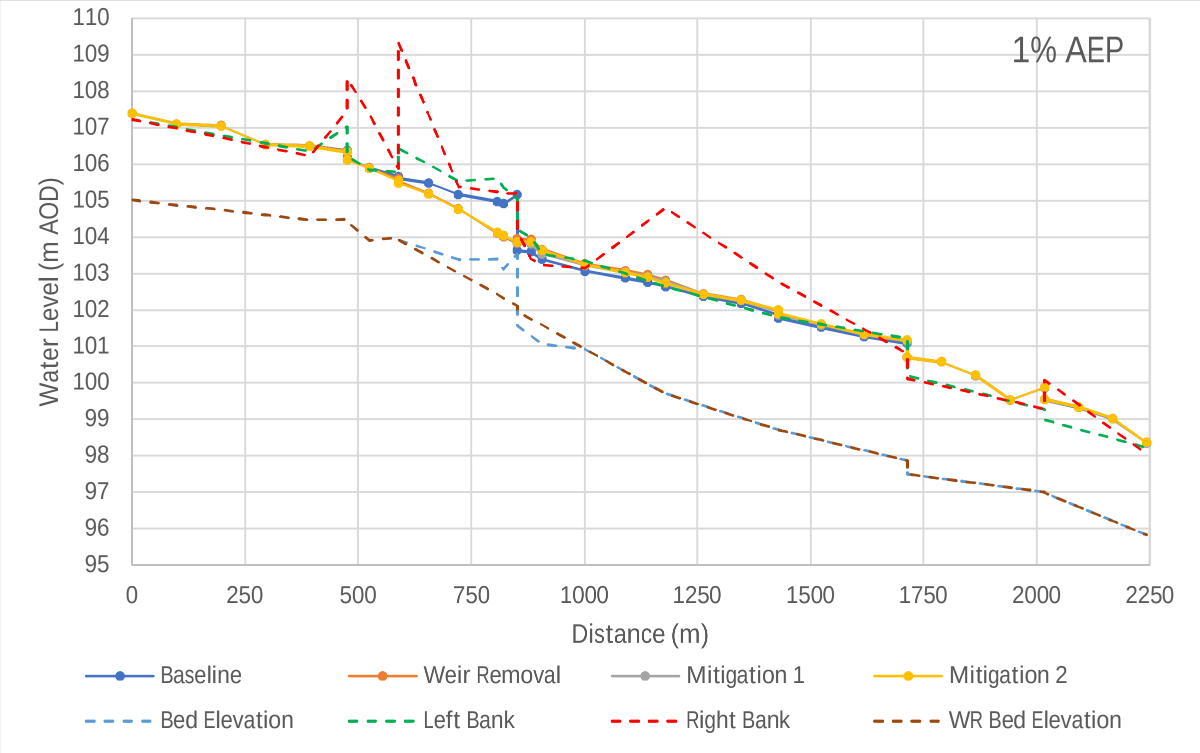


Figure 5-7 Water level long section.

5.4 Flood Consequence Assessment

The above results demonstrate that weir removal would have an impact on in-channel water level as a result of channel regrading. The reduction in water level upstream of the current weir location demonstrates a reduction in flood risk here as the channel capacity has increased due to the re-grading, as well as less water leaving the channel and passing through the floodplain. In-channel water level has increased downstream of the weir site for all weir removal scenarios. The water level increase here is limited and does not impact the flood risk of any infrastructure. While there may be a reduction in water levels across the floodplain, the flood boundary is so large that the difference is insignificant.

Weir removal would also have an impact on in-channel velocity and flow which varies upstream and downstream of the weir location. As weir removal results in an increased channel gradient and subsequent increase in velocity and flow around the weir location, as shown in Section 5.1 and 5.2, it is likely that scour will also increase here in the channel. This may have a detrimental effect on the surrounding ecology and geomorphology; however, it may also become dynamically stable. Changes in this location will not cause changes in flood risk but may change the consequences seen following flood events. The mitigation scenarios investigated here are potential ways of overcoming these changes, but further optimisation is required.

Appendix A Topographic Survey Data