Natural Resources Wales

Ynysybwl Flood Risk Management SOC

Longlist modelling report

Reference: 290076-ARP-00-XX-RP-CX-1010

P02 | 4 March 2024

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Job number 290076

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Document Verification

Project title	Ynysybwl Flood Risk Management SOC
Document title	Longlist modelling report
Job number	290076
Document ref	290076-ARP-00-XX-RP-CX-1010
File reference	4-50

Revision	**Date**	**Filename**	290076-ARP-00-XX-RP-CX-1010		
P01	19/01/2024	**Description**	First issue for comment		
			Prepared by	**Checked by**	**Approved by**
		Name	Charlotte Dunleavy	Adam Sinclair	Robin Campbell
		Signature			
P02	04/03/2024	**Filename**	290076-ARP-00-XX-RP-CX-1010		
		Description	Updated final issue addressing minor NRW comments		
			Prepared by	**Checked by**	**Approved by**
		Name	Charlotte Dunleavy	Adam Sinclair	Robin Campbell
		Signature			
		Filename			
		Description			
			Prepared by	**Checked by**	**Approved by**
		Name			
		Signature			

Issue Document Verification with Document ✓

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1. Introduction

Ove Arup and Partners Limited (Arup) has been appointed by Natural Resources Wales (NRW) to undertake a Strategic Outline Case (SOC) for the Ynysybwl Clydach Terrace Flood Risk Management Scheme. Hydraulic modelling is required to support the long listing of potential flood risk management options to reduce the risk of flooding to the 16 properties at Clydach Terrace. This technical note details the modelling process and flood risk outcomes of three different flood alleviation options, comprising:

- Increasing the height of the existing wall at Clydach Terrace.
- De-culverting of the Ynysybwl culvert.
- A flood storage area in the area north of Clydach Park.

1.1 Background and location

The site is located in Ynysybwl, Rhondda Cynon Taf (nearest post code: CF37 3LT, central grid reference: ST 06008 94561) as shown in Figure 1.

The Clydach is a small tributary of the River Taff which enters the Taff on its western bank midway between the confluences of the Rhondda and Cynon. The watercourse is short and steep in a confined upland valley where the course of the stream is flanked by residential properties.

Historically the river has been diverted. Clydach Terrace lies on the natural floodplain in a very constrained section of the Clydach valley upstream of a large culvert. The Terrace has historically suffered from severe flooding from records dating back to 1955. Notably during Storm Dennis in February 2020, flood waters from the Nant Clydach overtopped the highway wall which runs along the length of the Terrace, internally flooding of 16 properties. Flooding experienced was significant, with rapid onset and the internal depth of flooding to the lowest lying houses was reportedly up to 1.8m.

No formal flood defences are currently present at Ynysybwl although the highway wall acts as a de-facto defence. The river is prone to shoaling. NRW and its predecessor bodies have undertaken channel maintenance to remove shoal material from the river channel adjacent to Clydach Terrace.

2. Longlist option modelling

2.1 Baseline model

The options modelling has been undertaken using the NRW approved model of the Nant Clydach, developed by Arup in 2022. The model comprises a linked 1D-2D ESTRY-TUFLOW model, with the channel and structures represented in 1D and the floodplain and upper catchment represented in 2D.

A direct rainfall modelling approach had been used in response to concerns regarding hydrological routing accuracy in the upper catchment, the need to represent the contribution of surface water flood risk, the small size of the catchment and the likelihood of future model uses including the assessment of Natural Flood Management (NFM) in the upper catchment.

2.2 Option 1: Raised wall at Clydach Terrace

A highway parapet wall between Clydach Terrace and the river appears to act as a de-facto flood defence. The location and alignment of this wall is shown in Figure 1.

Figure 1 De-facto flood defence along Clydach Terrace (Google Streetview 2024 ©)

The wall is represented in the model using two z-shapes that have been informed by survey data collected in 2021. The first z-shape represents the base of the wall, and the second represents the crest. Option 1 comprises raising the height of this wall to provide an increased Standard of Protection (SoP) during flood events.

It was identified during initial test runs that there is a low spot on the right bank immediately downstream of the existing wall extent. In events equal to or exceeding the 1% Annual Exceedance Probability (AEP) plus 25% climate change allowance, the wall was being outflanked to the south with water flowing from the Nant Clydach at the low spot.

For the options modelling the wall has been extended downstream by approximately 6m in order to shore up the low spot. The extent and alignment of the original and extended wall is shown in Figure 2. The crest level of the wall has been raised by 10m, to effectively represent a “glass-wall” to determine the additional defence height required to prevent or reduce flooding to the Clydach Terrace properties.

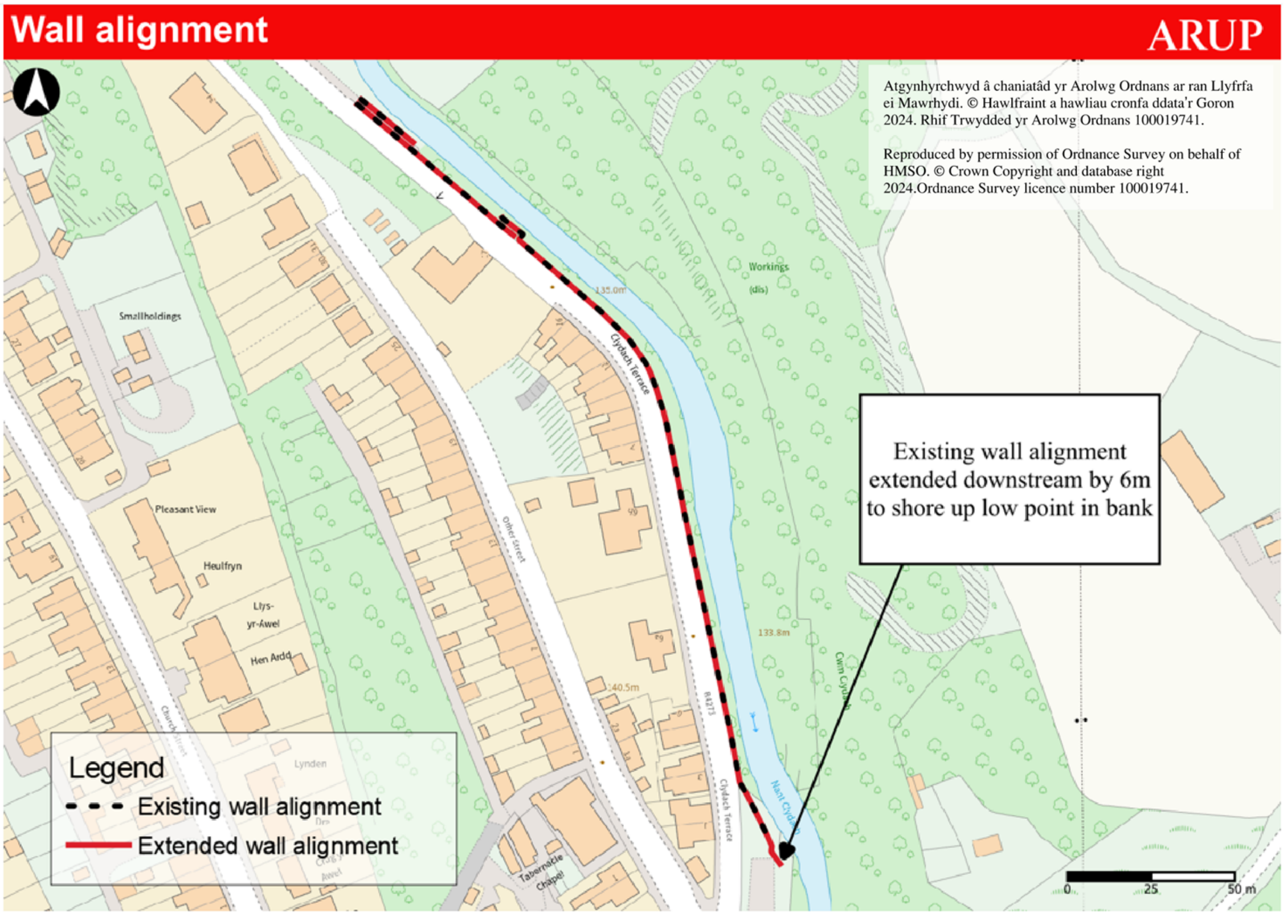

Figure 2 Extent of existing and proposed wall, which has been extended by approximately 6m downstream

After the Storm Dennis event, debris was observed in the channel downstream of Clydach Terrace, as shown in Figure 3.

Figure 3 Photo taken after Storm Dennis showing debris in channel

The severity of any in-channel blockage during Storm Dennis is not known, and therefore the impacts of this on water levels during the event is not understood.

In order to assess the sensitivity of the modelled wall option, Option 1 has been run both in the Existing scenario, with no blockage, and in the "Blockage 13" scenario, which has an 80% reduction in cross section area at the location of the observed blockage during Storm Dennis. This is considered an extreme blockage value which has been used to assess a potential "worse-case" scenario. The outputs from this theoretical model scenario have been used to assess the sensitivity of the Standard of Protection potentially offered by the wall option.

It is likely that at a future stage of assessment, further sensitivity testing would be undertaken to other model parameters, including channel roughness and shoaling in the channel. If this option were taken forward to construction, a residual uncertainty analysis would be undertaken to assess and determine the required freeboard.

2.3 Option 2: De-culverting of Ynysybwl tunnel

The Ynysybwl culvert is located approximately 80m to the south of Clydach Terrace. The structure comprises a large tunnel with a geometry that varies along its 110m length. The culvert is currently represented using 6 consecutive irregular culvert units, with cross section geometries informed by internal survey conducted by Edwards Diving Services in July 2021.

The culvert represents a potential constriction to flow during flood events, and therefore Option 2 comprises the theoretical complete de-culverting of this stretch of the Nant Clydach.

The irregular culvert units have been removed and replaced by open channel units. The geometry of the de-culverted reach has been represented by interpolating between the existing surveyed sections up and downstream of the culvert. This is considered an appropriate assumption as the two sections are relatively similar. Updated bank lines and points have been applied based on the available LiDAR data in the area.

Figure 4 summarises the schematisation of the option in the model.

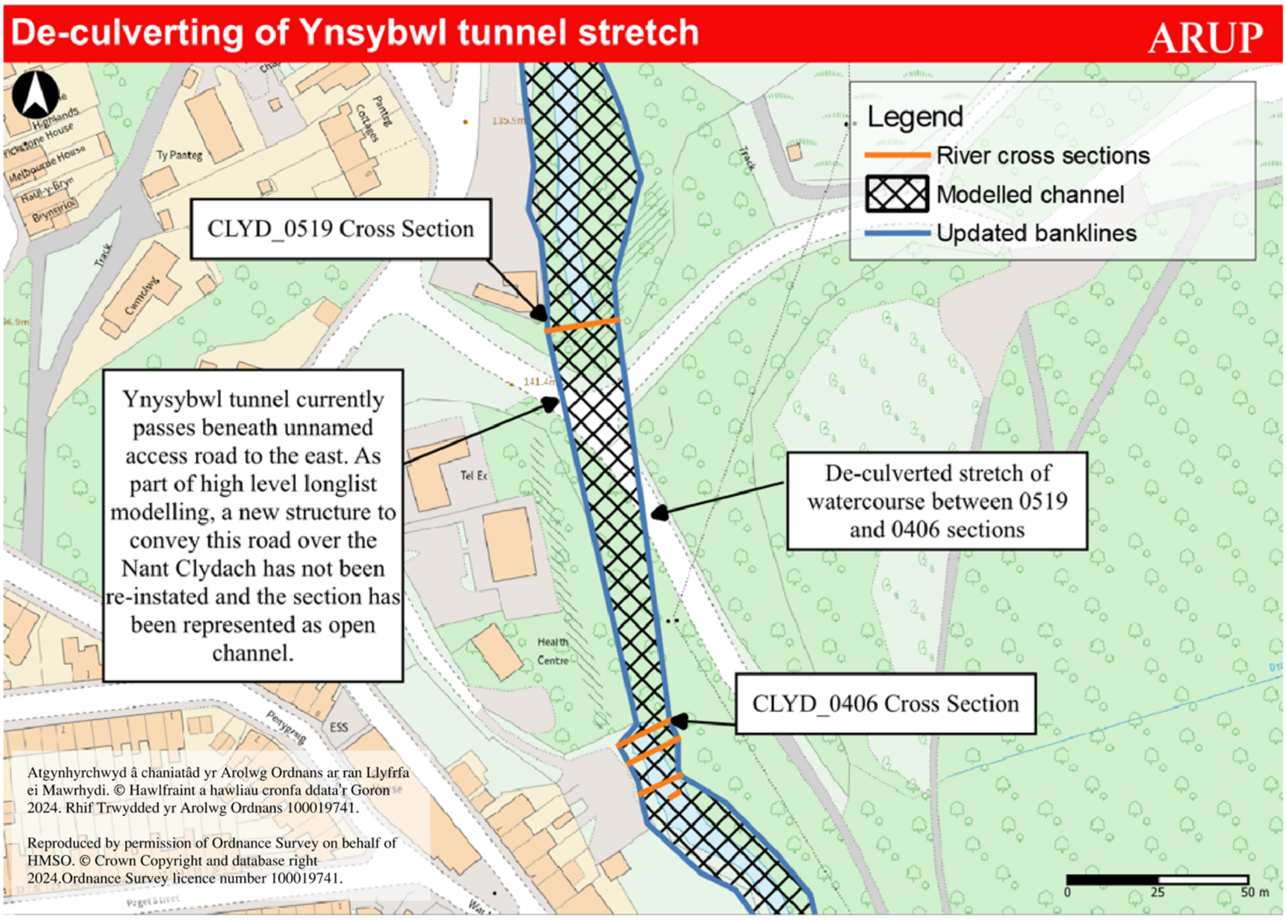

Figure 4 Schematisation of the Ynysybwl de-culverting option

There is an unnamed road which passes over the Ynysybwl culvert. The de-culverted channel has been modelled as passing directly through this road without a structure to convey the road over the now open channel. This approach is considered acceptable to undertake a high-level assessment of the impact to flood risk of de-culverting the channel. At a further stage of assessment, it will be necessary to incorporate a structure into the channel at this location, however this will be sized based on conveyance of flood flows and therefore is considered unlikely to act as a significant flow constriction. As such, the simplified assessment is considered appropriate at this stage.

2.4 Option 3: Flood storage area north of Clydach Park

To the north-west of Clydach Park there is an undeveloped area of scrub and trees. The topographic elevation of this area is shown in Figure 5. The area contains a depression with an elevation of approximately 146mAOD. To the east, the ground elevation is marginally higher, with a typical elevation of 147mAOD. The ground slopes steeply upwards to the south, reaching an elevation of 166mAOD on Clydach Road.

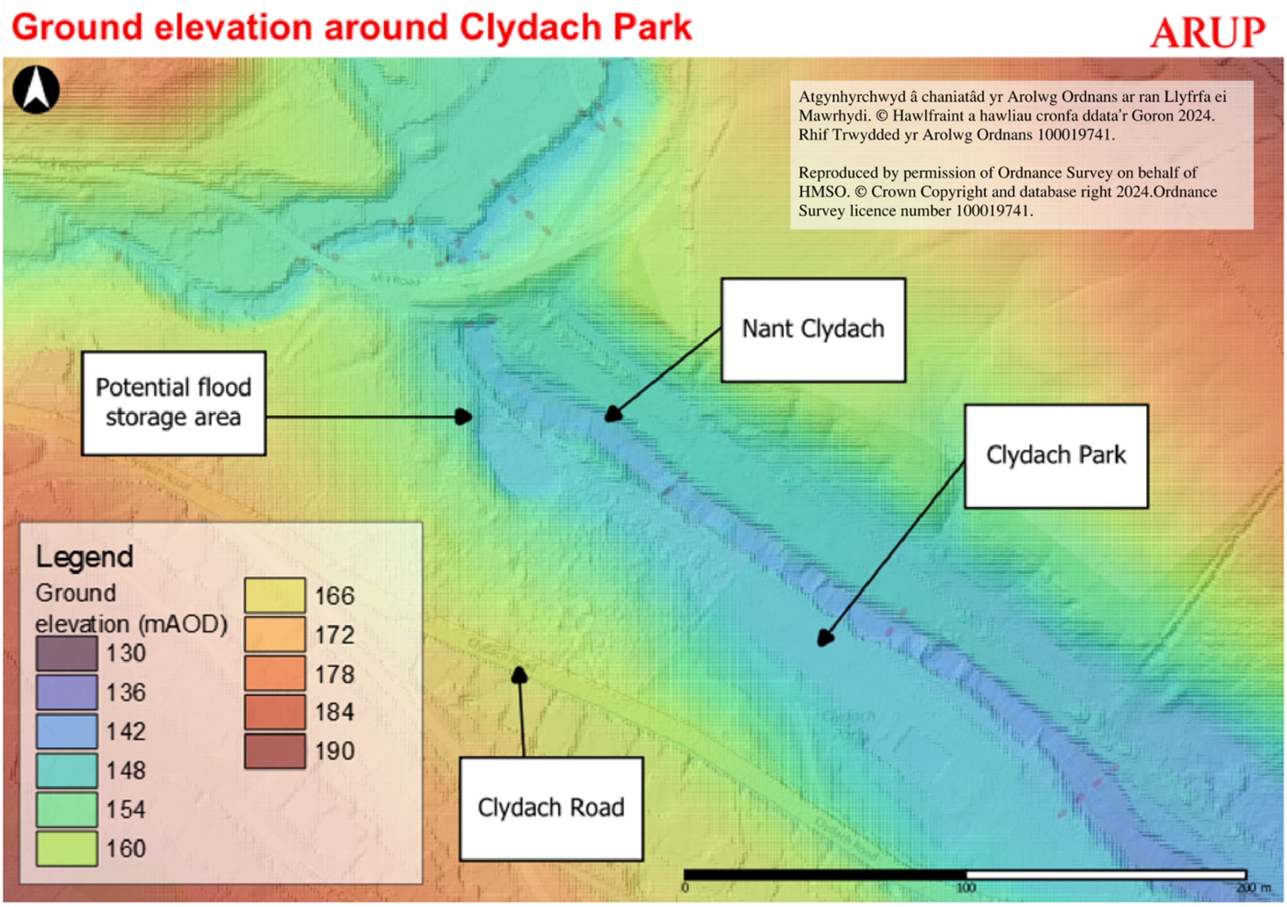

Figure 5 Ground elevations taken from LiDAR in the area around Clydach Park

Due to its proximity to the Nant Clydach, partially low lying elevation and lack of existing built receptors, this area has been identified as a potentially suitable area to re-route flow during periods of elevated water levels. The ground levels around the area are significantly higher than the elevation of the potential storage area, and therefore it is considered that the risk to other receptors as a result of using the area for flood storage is low.

Two modifications have been made to the model to encourage water to flow out of the Nant Clydach on the right bank when water levels are elevated:

- A weir structure has been added immediately upstream of Nant Clydach park. Existing maximum water levels are typically 1.5m lower than the elevation of the right bank in the 3.33% AEP, which is the onset of flooding to the properties on Clydach Terrace. As such, the weir structure has been set at an elevation 1.5m higher than the existing bed level at this location.
- As shown in Figure 5 above, there is a raised ridge of ground between the potential flood storage area and the Nant Clydach. This ridge has been lowered to the surrounding ground level to allow water to preferentially flow into the storage area. Similarly, the bank levels in the area, which are higher than adjacent ground levels, have been lowered.

Figure 6 summarises the changes that have been made in the model to represent Option 3.

Flood storage area schematisation

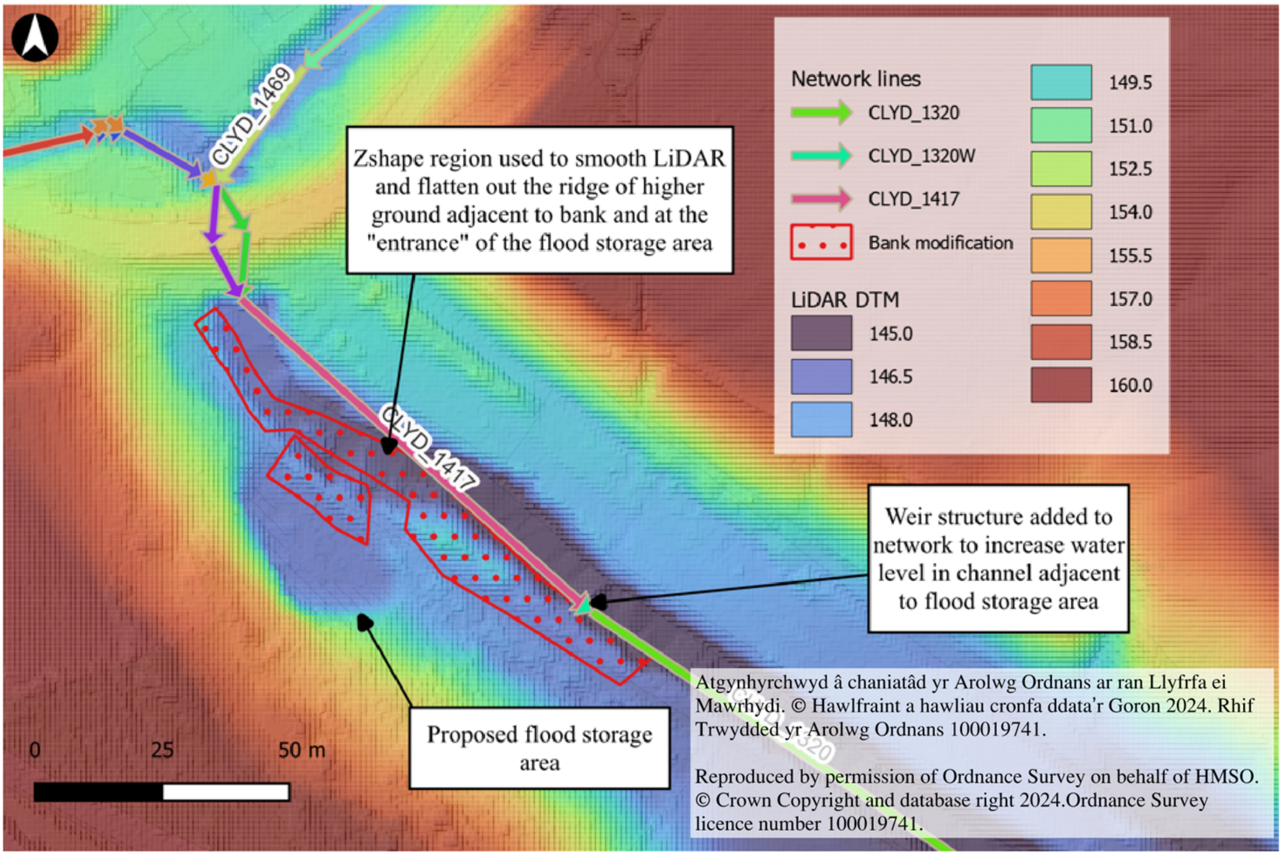

Figure 6 Schematisation of the flood storage area

3. Model results

3.1 Option 1: Raised wall at Clydach Terrace

The modelling indicates that raising the wall height at Clydach Terrace offers flood risk management benefits. When the height of the existing wall is raised, the model outputs show that water is prevented from leaving the Nant Clydach channel for all modelled events up to and including the 1% AEP event. However, in the 1% AEP event with an allowance for climate change, water overtops from the right bank, at a low spot downstream of the existing defence extent. Due to this, a modified version of Option 1 was run with the defence length extended downstream by 6m to shore up this low spot.

When the wall is extended downstream, the defence prevents flooding for events up to and including the 1% AEP with an allowance for climate change. In the 0.1% AEP event, although the wall itself is not overtopped, flooding occurs from the right bank downstream of the defence, which then circles north-wards to flood the properties on Clydach Terrace.

Figure 7 shows a depth difference map comparing the maximum water depths with Option 1 in place compared to the baseline flood depths in the 1% AEP event. The comparison indicates that there is a significant reduction in flood extent as the Clydach Terrace wall is no longer overtopped in this event. There is some residual flooding on Clydach Terrace road which arises from surface water flooding rather than the Nant Clydach.

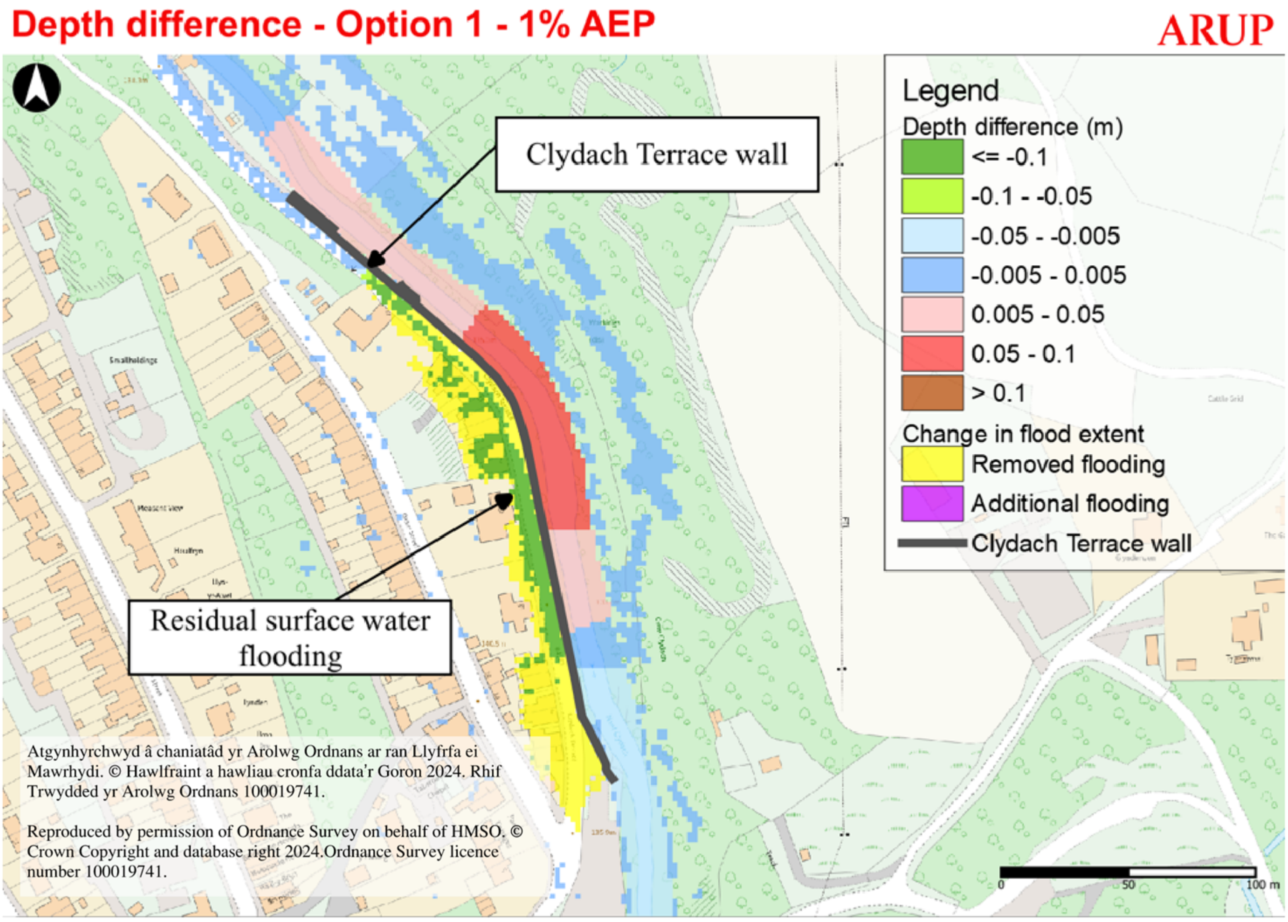

Figure 7 Depth difference map comparing outputs of the Option 1 model to the baseline model in the 1% AEP event

As mentioned previously, the wall has been represented in the model effectively as a glass wall to determine the required wall height to prevent overtopping. Figure 8 compares the maximum water levels in the Nant Clydach adjacent to Clydach terrace with the "glass-wall" in place, against the existing wall elevations.

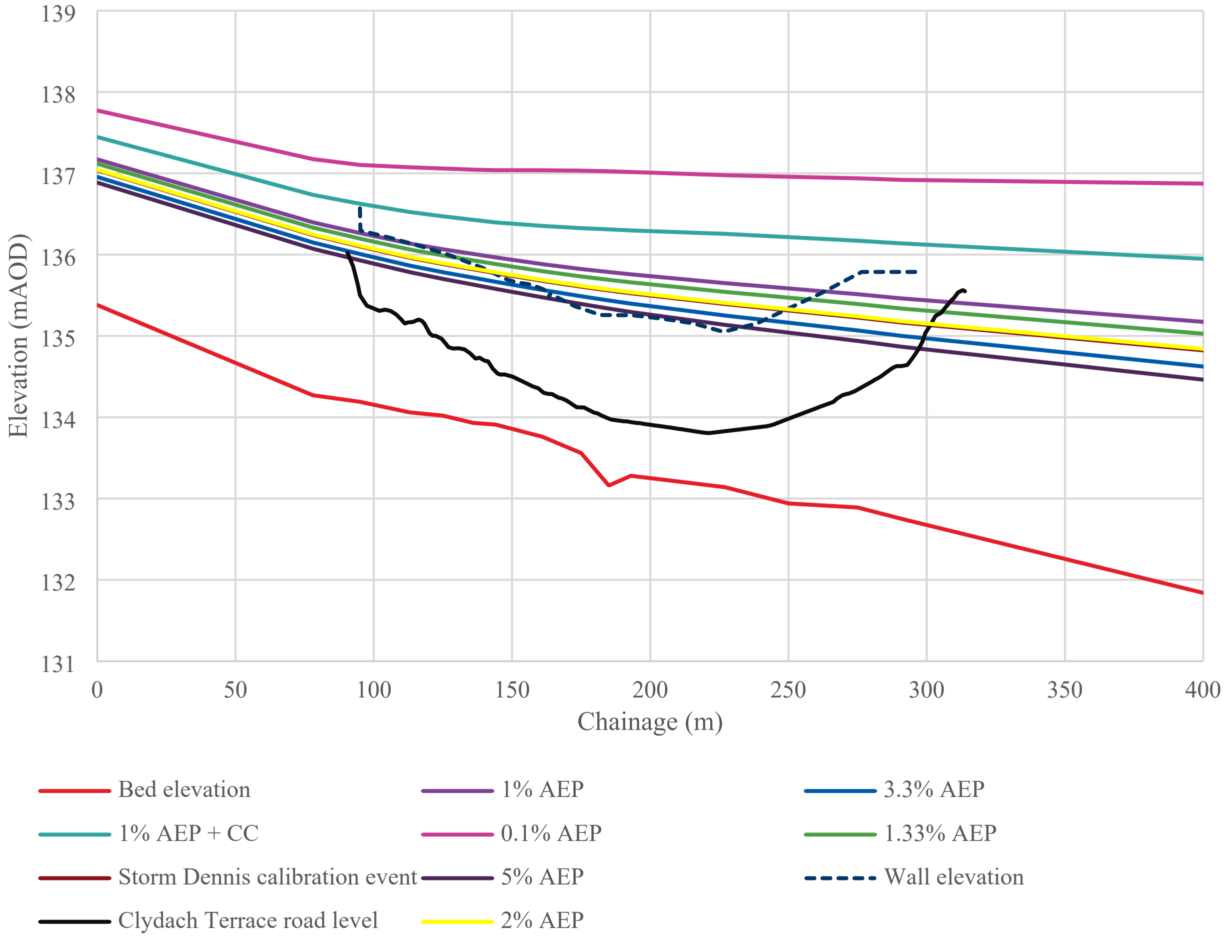

Figure 8 Comparison of maximum water levels with the wall extended downstream and height raised

The comparison indicates that to provide a 1% AEP SoP, the wall would need to be raised to approximately 136.2mAOD (not including an allowance for freeboard). At the lowest part of the wall, this represents an increase in wall height of approximately 1.2m (plus freeboard).

For larger events, including the 1% AEP with climate change allowance and 0.1% AEP, the wall would need to be raised by a significantly larger amount, up to a maximum of approximately 2m.

The sensitivity testing of the wall shows that when the theoretical 80% blockage is applied, the required wall height to prevent overtopping is increased, as shown in Figure 9. For example, in the 1% AEP event the height of wall required to prevent flooding would be approximately 1.4m, in comparison to 1.2m in the no-blockage scenario (excluding freeboard allowance).

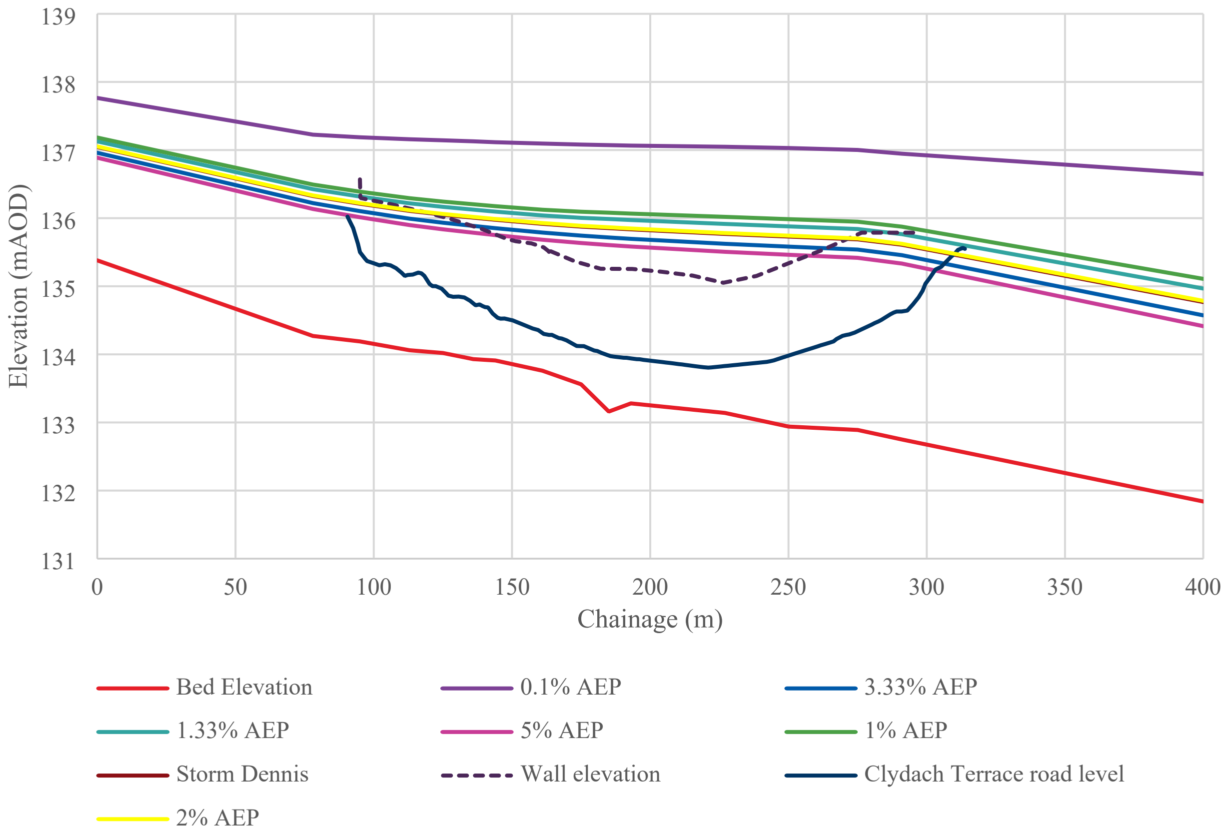

Figure 9 Comparison of maximum water levels with the wall extended downstream and height raised, with theoretical downstream channel blockage applied

Whilst this option is effective at reducing the risk of flooding, the feasibility and impact of increasing the wall height would need to be considered. The sensitivity testing has shown that the presence of blockage in the channel increases water levels adjacent to Clydach Terrace. A high blockage value of 80% has been used as a “worst-case” scenario in terms of potential blockage in the channel. The management of blockage risk should be considered at a future stage of appraisal. The residual risk of exceedance events and from localised surface water ponding should also be considered.

Additionally, the wall heights detailed here do not include an allowance for freeboard. This will be assessed and added in later stages, to account for residual uncertainty in the modelling and hydrological assessment.

3.2 Option 2: De-culverting of Ynysybwl tunnel

De-culverting the Ynysybwl culvert reach means that more water is passed downstream and therefore water levels through the reach are reduced. The modelling indicates that this option may reduce flooding in smaller order events. For example, Figure 10 shows a comparison of flow being passed downstream of Clydach Terrace in the 3.33% AEP event. In the baseline scenario, peak flows downstream of Clydach Terrace are 32.6m^3/s. When the culvert is removed, the flows increase to 33.3m^3/s, an increase of 0.7 m^3/s.

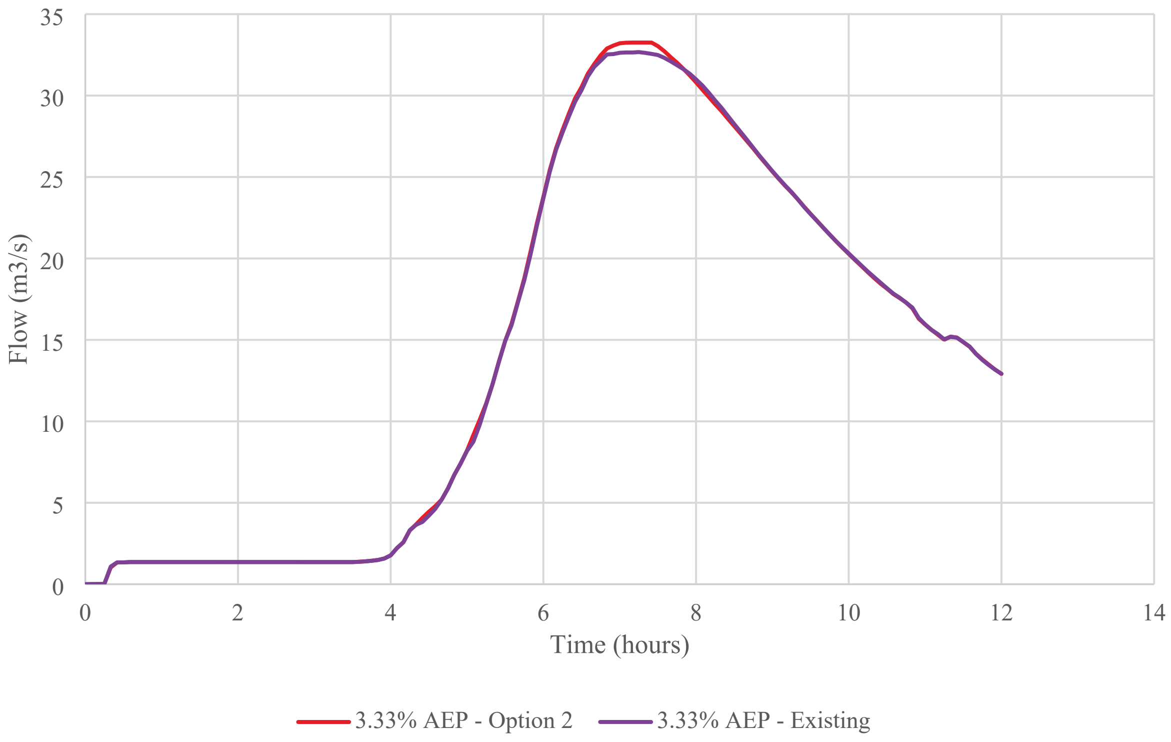

Figure 10 Comparison of flows downstream of Clydach Terrace in the 3.33% AEP event in the de-culverted and existing scenarios

The increased conveyance downstream of Clydach Terrace results in a water level that is reduced upstream of the culvert entrance. Figure 11 shows a long section of maximum water level in the 3.33% AEP event in the baseline and de-culverted option scenarios.

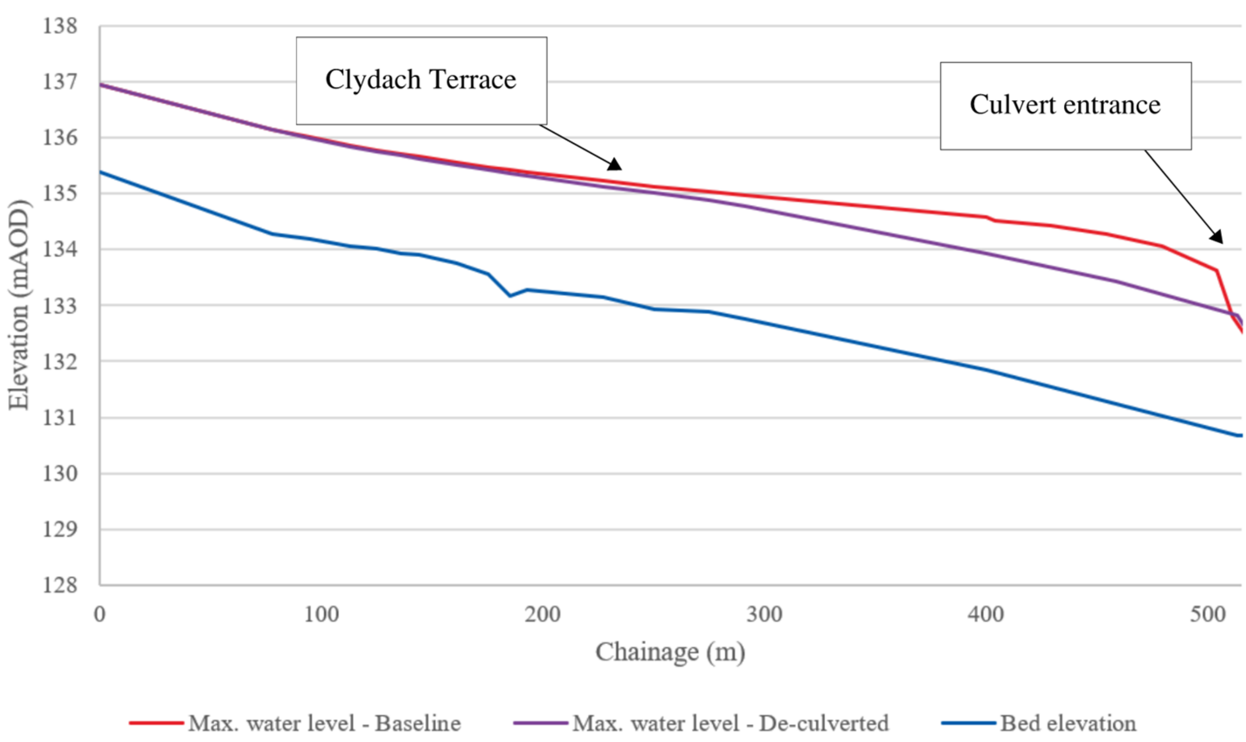

Figure 11 Long section of maximum water level in the 3.33% AEP event in the baseline and de-culverted option scenarios upstream of Clydach tunnel

Figure 12 shows a depth difference map comparing the Option 2 model outputs to the baseline in the 3.33% AEP event.

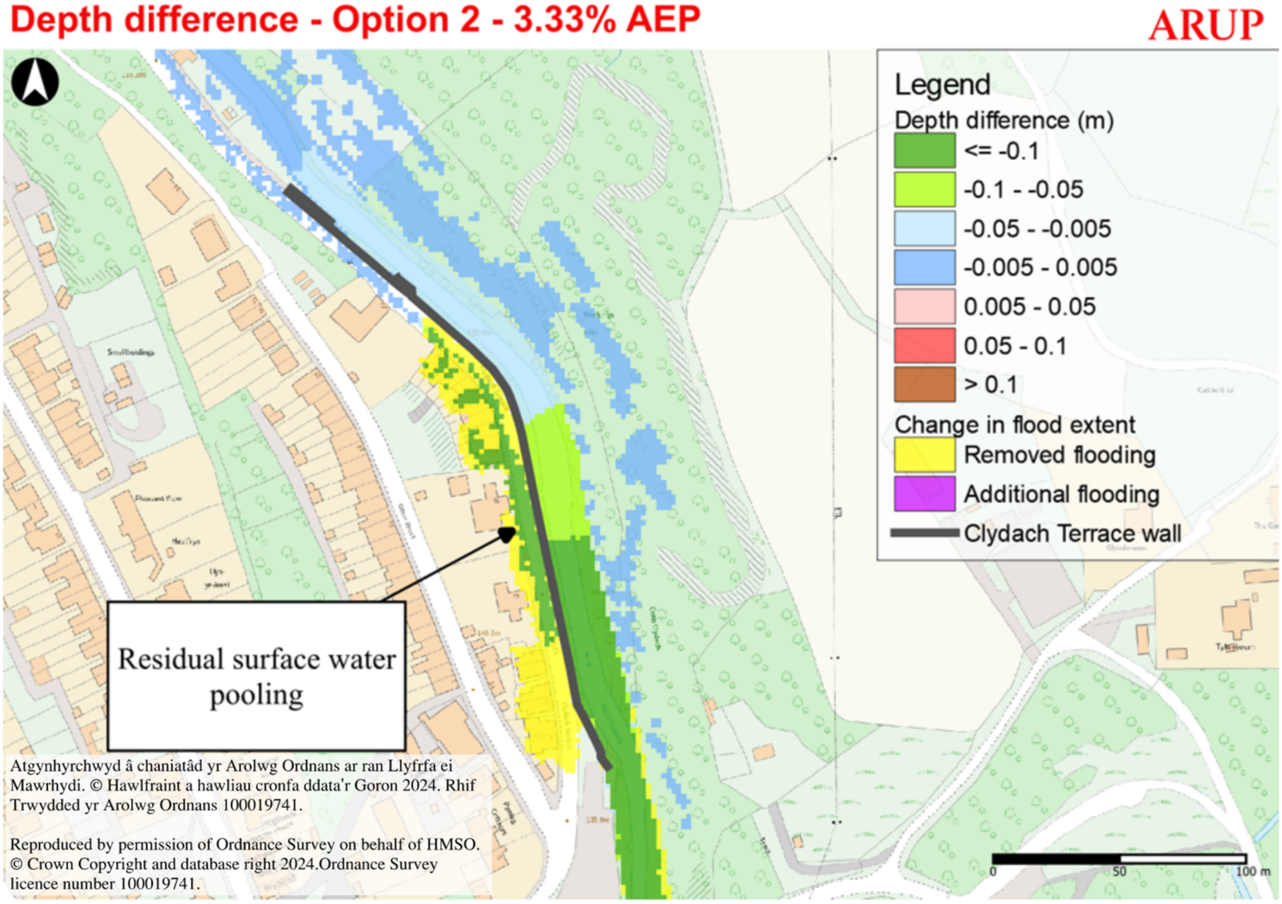

Figure 12 Depth difference map comparing outputs of the Option 2 model to the baseline model in the 3.33% AEP event

In the 3.33% AEP event, de-culverting of the Ynysybwl culvert means that water does not overtop the existing wall at Clydach Terrace. As such, there is a reduction in flood risk to the properties on Clydach Terrace for this event.

In events equal to or larger than the 1.33% AEP event, Option 2 similarly reduces levels at the culvert inlet, as shown in Figure 13.

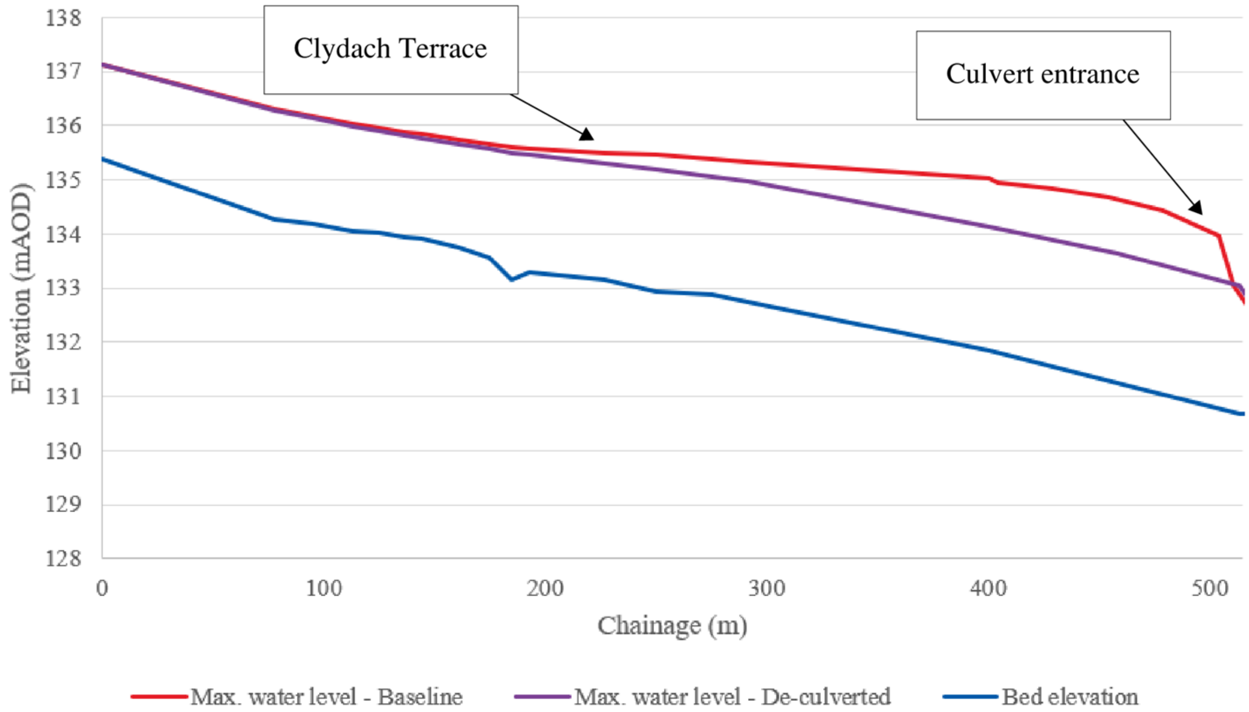

Figure 13 Long section of maximum water level in the 1.33% AEP event in the baseline and de-culverted option scenarios upstream of Clydach tunnel

However, in the 1.33% AEP event, the reduction in water level is not large enough to prevent overtopping of the Clydach Terrace wall. The flood depths and extents are marginally reduced; however the scale of the reduction is not large enough to remove the risk of internal property flooding and therefore the Option does not provide any benefit in terms of protecting these properties. Figure 14 shows a depth difference map comparing the Option 2 model outputs to the baseline in the 1.33% AEP event.

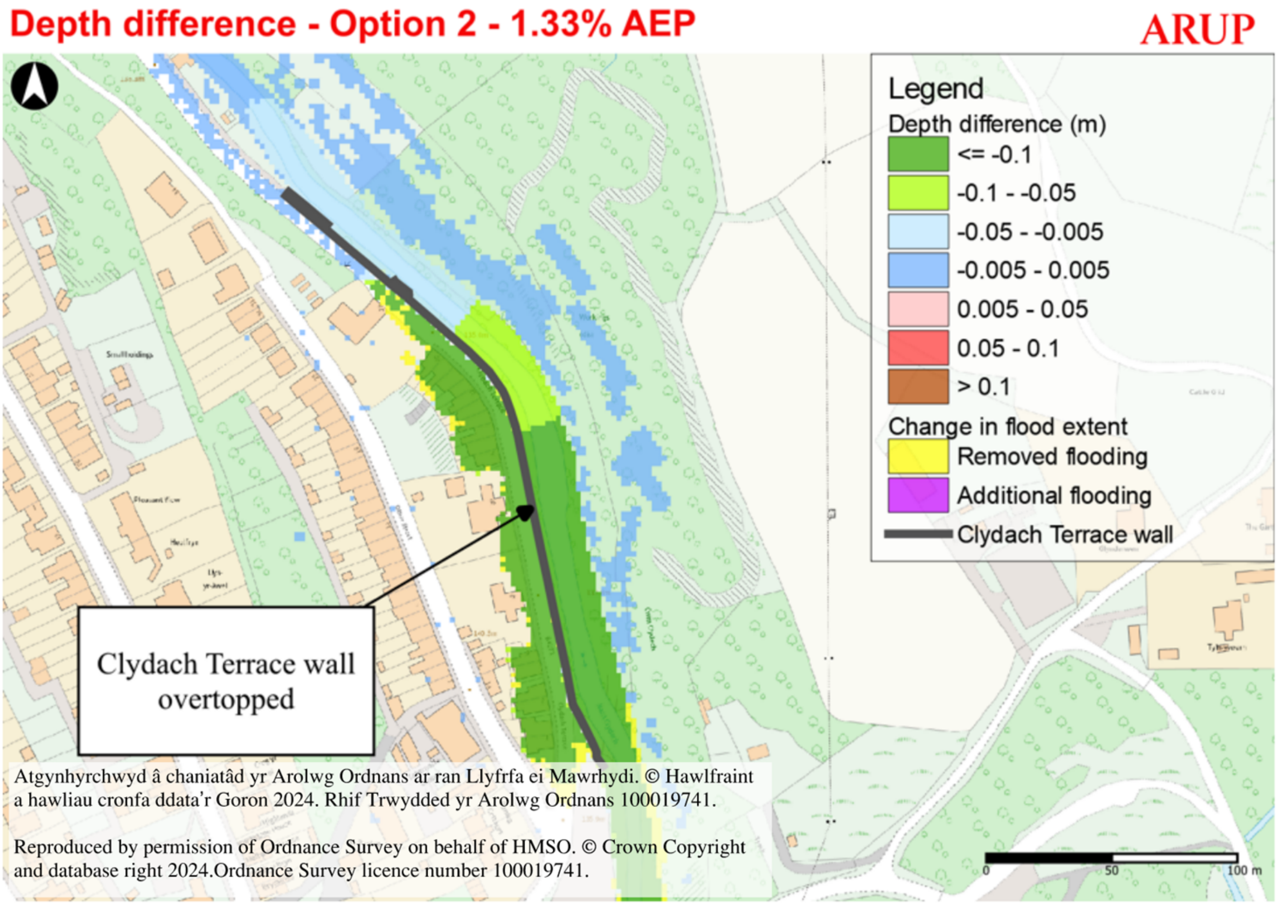

Figure 14 Depth difference map comparing outputs of the Option 2 model to the baseline model in the 1.33% AEP event

The model outputs indicate that the de-culverting option provides a significant reduction in flood risk in lower order events only. For higher severity events (1.33%AEP and above), there is a reduction in the flood depths that is typically in excess of 0.1m. However, the flood depths on Clydach Terrace in this event are generally between 0.9-1.7m in the baseline scenario. As such, even with the reduction in flood depths, the level of risk to the properties on Clydach Terrace remains high.Due to the increase in flow passing downstream, there is a potential for detrimental impact on communities downstream that would need to be investigated.

3.3 Option 3: Flood storage area north of Clydach Park

The alterations made to the model to represent Option 3 mean that the flood storage area fills during lower order return period events, such as the 3.33% AEP. However, the option does not provide a significant benefit in terms of flood depths and extents at Clydach Terrace. In the 3.33% AEP event, depths are reduced by 1-2mm on Clydach Terrace. Figure 15 shows a depth difference map comparing maximum water depths in the Option 3 model scenario to the baseline scenario in the 3.33% AEP flood event. This illustrates that although flood depths and extents are increased in the flood storage area, there is no significant (classified as >5mm) reduction at Clydach Terrace.

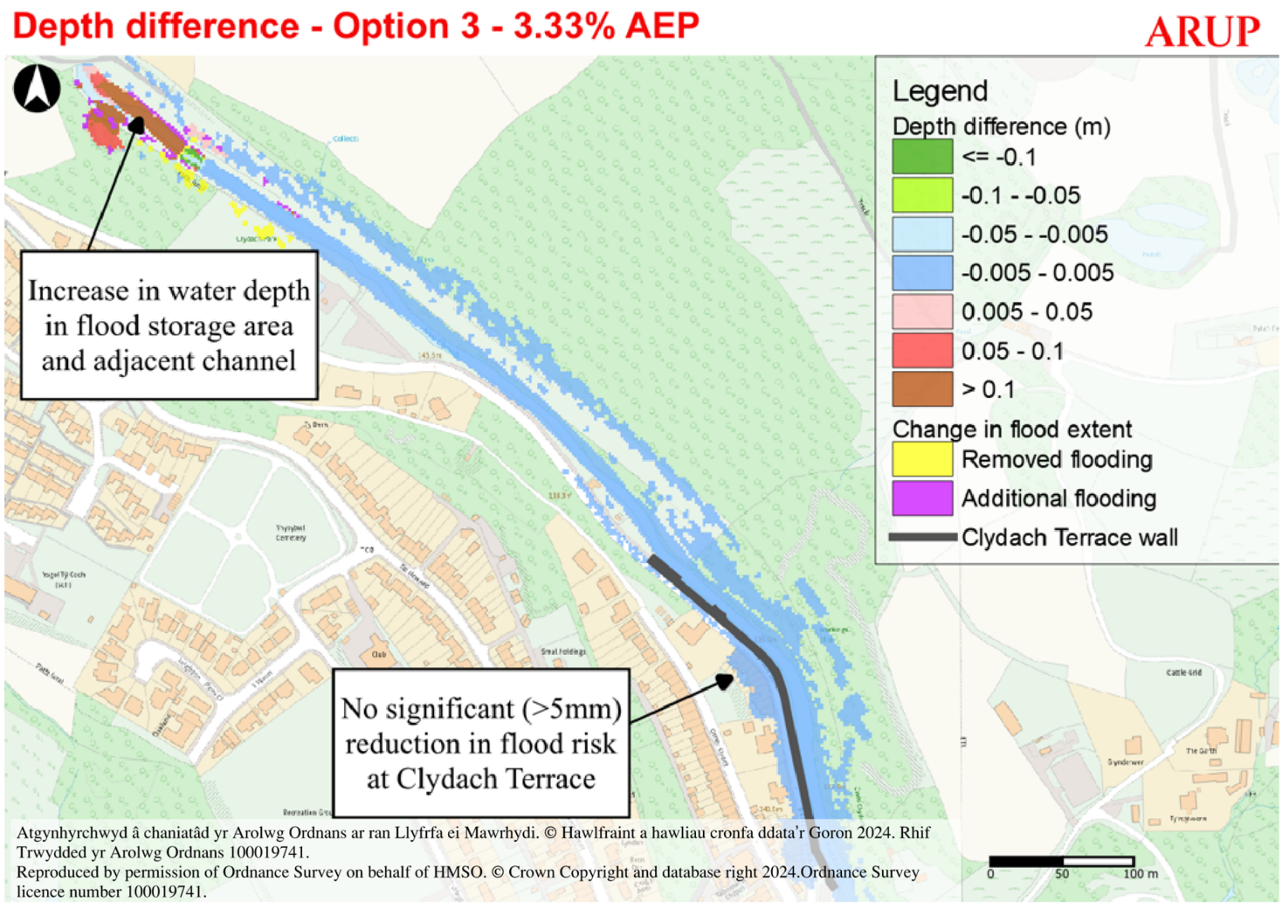

Figure 15 Depth difference map comparing outputs of the Option 3 model to the baseline model in the 3.33% AEP event

Figure 16 shows a comparison of the flow hydrograph in the Nant Clydach adjacent to Clydach Terrace in the 3.33% AEP event and the 5% AEP event. The onset of flooding to the Clydach terrace properties occurs in the 3.33% AEP event, however in the 5% AEP event the wall is not overtopped, and flooding does not occur.

To prevent flooding in the 3.33% AEP event from occurring, the flood storage area would need to store enough water to reduce the peak flows at Clydach Terrace to be comparable to peak flows in the 5% AEP event. An approximation of the amount of flow that would need to be stored to effectively reduce the peak 3.33% AEP flows to a value equal to or lower than the 5% AEP peak flow value has been calculated. The amount of storage required to reduce a 3.33% AEP peak to a 5% AEP would be approximately **10,000m^3**.

The same calculation has been repeated for a 1.33% event. In the larger event, the storage volume required is approximately **56,200m^3**, excluding allowance for climate change.

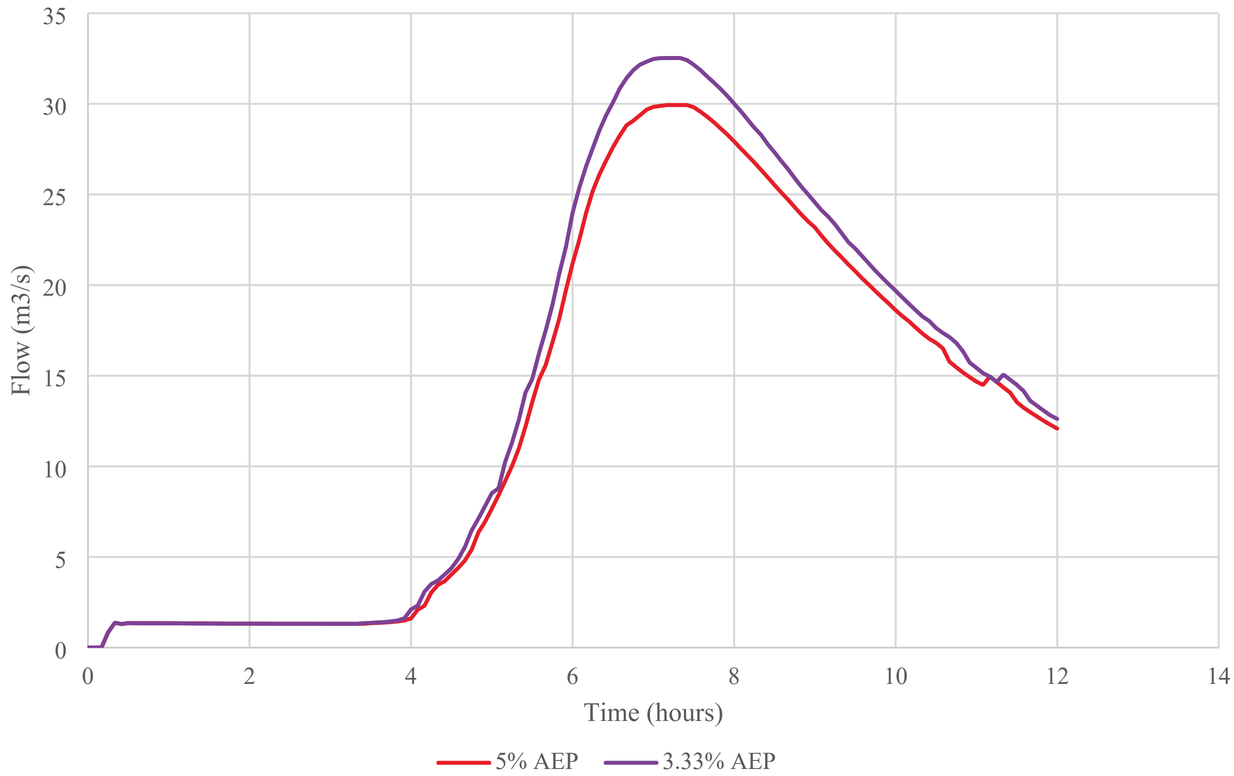

Figure 16 Comparison of flows at Clydach Terrace in the 5% and 3.33% AEP

The potential flood storage area to the north-west of Clydach Park has an area of approximately 1,300m^2. As such, substantial depths within the storage area would be required to provide the necessary reduction in hydrograph volume to prevent flooding at Clydach Terrace. For example, a depth of approximately 8m would be required to store enough flow to reduce a 3.33% AEP event to a 5% AEP event at Clydach Terrace. This is not feasible based on the geography of the surrounding area. Additionally, the Nant Clydach sits within a narrow and constrained valley, and therefore it is considered unlikely that the required space for flood storage could be found adjacent to the watercourse throughout Ynysybwl.

The volume required also means that any flood storage area is likely to exceed the Registration Threshold for reservoirs that are regulated under the Reservoirs Act 1975 and would essentially mean construction of a new reservoir in Ynysybwl. Based on the modelling assessment and the volume calculations, this option is not considered feasible.

4. Conclusion

A high-level modelling exercise has been undertaken to determine the feasibility of three generalised flood risk management options to prevent flooding to Clydach Terrace in Ynysybwl. The three options comprise:

1. Raising the level of the existing de-facto defence along Clydach Terrace.
2. De-culverting of the Ynysybwl Culvert
3. Installing a flood storage area to the north-west of Clydach Park.

The modelling has indicated that de-culverting of the channel provides some benefit in the lower order return period events, namely the 3.33% AEP as this option improves conveyance and reduces the build-up of water at the upstream end of the existing culvert. However, in larger events the de-facto defence is still overtopped and results in residential flooding to the properties.

The flood storage area is shown to fill during lower return period events; however, the storage area does not provide an appreciable amount of storage when compared to the volumes of water in the channel and being passed forward to Clydach Terrace. A high level calculation of the approximate amount of water that would need to be stored to reduce peak flows to those in the 5% AEP event, when flooding does not occur, has been undertaken. The assessment indicates that for the 3.33% AEP and 1.33% AEP events, a volume of approximately 10,000m^3 and 56,200m^3 would need to be stored for these two events respectively. This amount of storage would be difficult to provide within the spatial constraints and would also essentially mean construction of a new reservoir in Ynysybwl.

Raising the wall height is shown to be provide flood risk management benefits to the Clydach Terrace properties. By extending the existing de-facto defence length by approximately 6m downstream and increasing the height of the wall, the defence can provide a standard of protection up to the 1% AEP with an allowance for climate change. However, this would require a relatively substantial increase in height of the existing defence. The sensitivity testing of the model has also indicated that a blockage of the channel might impact the SoP offered by the defence as water levels in the channel adjacent to Clydach Terrace would increase. Additionally, the modelling undertaken as part of this exercise was undertaken at a high level only using a glass-wall to represent the Clydach Terrace wall height and as such further work is required to understand the residual risk during exceedance events.

There are a number of limitations of the modelling study and longlist option appraisal that should be considered when appraising the potential options:

- The catchment is ungauged, and therefore the model cannot currently be fully calibrated to gauge data. A model verification exercise was undertaken as part of the model build process which compared the model outputs to wrack marks and flood extents recorded during and after Storm Dennis. The comparison concluded that generally the model could reproduce the flood extents observed, however it was not possible to provide an assessment of the flood AEP of the Storm Dennis event;
- No freeboard analysis has been undertaken subsequent to modelling of the longlist options. The wall option (Option 1) uses a glass-wall representation of the proposed Clydach Terrace defence;
- For the de-culverting option, no replacement structure to allow the existing access road to cross over the Nant Clydach has been modelled. A high level assumption has been made that the new structure would have a larger conveyance capacity than existing and would therefore have a very minor impact on water levels; and
- High level volume calculations have been used to better understand the total amount of water volume that would need to be stored to provide an appreciable benefit to flood risk at Clydach Terrace. The calculations are intended as a check to inform feasibility in combination with an understanding of the available amount of storage in the floodplain.

Further information regarding the development of the baseline model is provided in the Ynysybwl Modelling Project Model Technical Report (Document reference 290003-ARP-YX-RP-00-00-W0-0001).

4.1 Modelling next steps

The longlist modelling exercised has identified that raising the wall height of the Clydach Terrace de-facto defence offers flood risk management benefits for the properties on Clydach Terrace. At a future stage, modelling would be necessary to identify the wall height needed to provide the required Standard of Protection for the properties.

Additionally, an assessment of required freeboard should also be undertaken to quantify the additional wall height needed to account for inherent uncertainty in the modelling and hydrology assessments that have been undertaken.