Cyfoeth Naturiol Cymru
Natural Resources Wales

Ynysybwl Flood Risk Management Outline Business Case

Executive Summary

Properties along Clydach Terrace in Ynysybwl, Rhondda Cynon Taf, Wales, are at high fluvial (river) flood risk from the Nant Clydach. This Outline Business Case (OBC), which builds on the previous Strategic Outline Case (SOC), has been developed to further assess a shortlist of Flood Risk Management (FRM) options that aim to reduce this risk. The appraisal has sought to take an evidence-based, holistic approach to better understanding flood risk and the case for FRM options, considering the impact on residents, both now and in future. The OBC follows the HM Treasury Better Business Cases approach and WG's FCERM Business Case Guidance (FCERM-BCG).

The problem: The physical and mental impact of living with risk and dealing with the aftermath of flooding is far-reaching. National studies have found the risk of probable depression, anxiety or Post-Traumatic Stress Disorder is six times higher in people whose homes have been flooded when compared to those unaffected[1]. Flooding can have a devastating impact on people's lives, with multiple impacts that can interact with and exacerbate each other[2].

During Storm Dennis in February 2020, 16 properties along Clydach Terrace experienced rapid inundation, with internal flooding recorded up to 1.96m deep, trapping residents in their homes and posing a significant risk to people and property. Further flooding was experienced during Storm Bert in November 2024 when at least two properties recorded internal flooding. Living with the ongoing risk of flooding significantly impacts residents of Clydach Terrace and the wider Ynysybwl community.

Since October 2023 Welsh Government (WG) has funded the National Flood Forum (NFF) to offer support to Clydach Terrace residents including establishing a Flood Action Group and a Flood Action Plan and facilitating partnership working between Risk Management Authorities and the community. At NRW's request, NFF collated a Community Narrative (appended in full) summarising some lived experience of residents. "The huge financial, practical and emotional strain of flooding… impacts every aspect of our lives, day after day."

Currently properties are offered some standard of protection (SoP) from fluvial flooding by a circa 1.2m high Rhondda Cynon Taf County Borough Council highway wall running parallel to the river. However, it is not likely the wall was constructed as a formal flood defence, and its current condition inhibits its ability to be relied on as a flood defence asset. During Storm Bert the wall overtopped, and the river water was observed leaking through onto the B4273. An inspection in January 2025 found the wall condition to have visually deteriorated compared with 2022 imagery, with failed rendering, exposed masonry blockwork and several cracks. The residual life of the asset is not known but retaining floodwater that then overtops the asset is accelerating its deterioration and estimates suggest less than 20 years. Flood modelling indicates the wall is overtopped in the present day Business as Usual (BAU) scenario between the 1 in 10 and 1 in 20 annual chance events, assuming the existing wall does not breach beforehand. By the end of the 100-year appraisal period, significant flooding is predicted every other year if the wall is assumed to have failed.

[1] The English National Study for Flooding and Health: First year report, *Public Health England (2017)*

[2] Every Time it Rains, *British Red Cross (2022)*

Flood hazard to Clydach Terrace is exacerbated by the flashy response of the upstream catchment. Following rainfall in the catchment, the onset of flooding from typical river flows to peak flood conditions can be as little as 3 hours, and no flood warning system specific to the Nant Clydach is available. Industry-standard flood hazard assessments found that in a 1 in 100 annual chance event for the current day BAU scenario, predicted flood water speed and depth presents a "*danger for most/all people"* adjacent, including highway users and those in 16 properties along Clydach Terrace. The frequency and intensity of flooding is predicted to increase due to climate change and the current SoP could rapidly decline through the potential deterioration of the highway wall. Over a 100-year period, factoring in climate change and ongoing river maintenance, the wall could eventually fail and be breached. If not replaced with a flood defence, the risk to people and highway users nearby will rise, leading to "danger for most/all people" adjacent to the section of river in the study area, which includes 25 residential properties.

The appraisal: The SOC relied on available information including high-level hydraulic modelling, flood records, and community and stakeholder engagement. It appraised a longlist of options including a flood defence wall, removal of the downstream tunnel, increased river capacity, natural flood management (NFM), upstream flood storage, flood warning system, removal of properties at risk, and property flood resilience (PFR) measures. It recommended a shortlist of do-something options (a flood defence wall at two different SoPs, and the purchase by agreement of properties at risk along Clydach Terrace) should be considered in more detail. The discarded longlist options were discounted for varying reasons including construction challenges, environmental impacts, estimated cost or inability to meaningfully reduce flood risk,

To better understand the viability of FRM options relative to BAU and Walkaway (WAW), costs, impacts and benefits have been appraised in accordance with the FCERM-BCG. Work included stakeholder engagement, updating hydraulic modelling, environmental surveys, specialist studies, detailed benefit and cost calculations for economic assessment and consideration of wider benefits including the wellbeing of the local community and net environmental impacts.

Replacing the highway wall with a larger engineered raised flood defence structure would better contain fluvial flooding within the river. Its height depends on the desired SoP. Due to the fast-responding catchment and the lack of river flow data, there is a degree of uncertainty with flood risk predictions, and thus a higher level of freeboard (the extra height added to a flood defence wall to account for uncertainties in flood modelling, wave action, storm surges, and water level changes, reducing the chance the structure is overtopped in extreme conditions) is required to ensure confidence in the desired SoP. Based on hydraulic modelling outputs and including a minimum freeboard allowance, a wall height, varying along its length, from 3.5 metres to 4.5 metres above road level, has been estimated as required to contain a 1 in 100 annual chance present day event. Such a structure is likely to significantly impact views along the residential street, impinge on the highway and river corridor and pose significant construction challenges. Further, although modelling shows the wall reduces fluvial flood risk to properties and to road users, there remains residual risk of overtopping during exceedance events. As the impacts of climate change are increasingly felt, the chance of exceedance increases and modelling shows that once the wall is overtopped, the residual hazard is very high. Regardless of SoP, due to its low-lying position compared to the surrounding community, measures will also be required to manage residual ponding pluvial flood risk, such as property level flood resilience.

Purchase by agreement for flood risk management is untested in Wales, and as such carries procedural risks and uncertainties. This option assumed removing the 16 properties in the current day BAU "*danger for most/all people*" zone, through acquisition and subsequent demolition in accordance with the relevant legislation and compensation code. Following implementation of this option, hazard modelling predicts conditions would still pose a "*danger for most/all people"* adjacent (highway users) during a present-day 1 in 100 annual chance event. Over the 100-year appraisal period allowing for climate change, assuming river maintenance ceases, the wall is breached and not replaced with a flood defence, "danger for most/all people" adjacent, including highway users, increases to 11 properties in the study area.

For either do-something option, potential delivery would be estimated by Autumn 2029. This is due to the relative complexity of the design, negotiations, environmental surveys and studies required to inform permit applications. The constrained nature of the site, the utilities present and construction challenges adjacent to the Nant Clydach may require the flood defence wall to be constructed over two consecutive summer periods.

Whilst the ongoing risk of flooding understandably impacts residents, the option of a raised defence flood wall will impact everyday life through the visual impact and potential for exceedance events.

The shortlisted options reduce the hazard to properties on Clydach Terrace through different mechanisms and present a markedly different residual flood risk picture that changes over the appraisal period. Initially the raised defence flood wall better protects the community however over time the likelihood of hazardous overtopping increases. Meanwhile, purchase by agreement addresses properties and people most at risk, but risk to highway users and the wider community remains and is dependent on the deteriorating condition and residual life of the highway wall which is acting as a flood defence.

The economic case for change: The economic case for the above two do-something options has been assessed in FCERM terms. The Present Value Cost (PVc) and the Present Value Benefit (PVb) are calculated over the 100-year appraisal period and compared with the baseline options of WAW and BAU.

For cost estimating purposes (while freeboard assessments were on going), a flood defence wall option was designed using an assumed wall height of 3 metres. While this estimate has proven to be lower than subsequent studies recommended, it was deemed appropriate to provide indicative estimates of delivery costs, which could be amended as the understanding of freeboard and the design developed further. The estimated PVc for this wall is £5,531k. This excludes ongoing maintenance costs and later-calculated freeboard estimates. Any increase in wall dimensions due to inclusion of additional freeboard will result in higher costs. Providing protection against a 1 in 100 chance annual event SoP, provides an estimated PVb of £2,593k. Therefore, the Benefit Cost Ratio (BCR) for a wall option greater than 3 metres, which can achieve 1 in 100 chance annual event SoP, is less than 0.47.

The case for a flood defence wall with a 1 in 50 chance annual event SoP has been considered using available information. Analysis indicates PVb is approximately £1,043k, reflecting the higher residual flood risk in this scenario. The PVc is estimated at £5,442k based on an assumed height reduction of around 0.27m from the 3 metre high wall design. The relatively small change reflects slight savings in construction material and effort, however costs such as utility diversions will be unchanged. This high-level assessment

indicates that lowering the SoP provided by the wall would not reduce the costs substantially but weakens the benefits. The economic case reduces to an estimated BCR at 0.19.

For the purchase by agreement option on flood risk grounds in combination with WAW assumptions, the PVc has been estimated as £5,333k and the PVb is £1,258k. The BCR is 0.24. For the purchase by agreement option on flood risk grounds in combination with BAU assumptions, the PVc has been estimated as £5,333k and the PVb is £2,641. The BCR is 0.50.

Sensitivity analysis found the FCERM economic case to be clear. For the flood defence wall option, a reduction in whole life costs of 53%, along with a substantial increase of the scale of the wall to allow for a suitable freeboard, would be needed for the BCR of the scheme to be economically viable.

For the Purchase by Agreement option on flood risk grounds, in combination with BAU assumptions, a reduction in whole life costs* of 51% would be needed for the scheme to have a BCR >1. For the Purchase by Agreement option on flood risk grounds in combination with WAW assumptions, a reduction in whole life costs of 77% would be needed for the scheme to have a BCR >1.

**Whole life cost estimates cover the purchase value of properties, related fees (such as vendor and purchaser fees), demolition, site remediation and maintenance costs, and project delivery expenses (including staff and consultant fees). These estimates also factor in optimism bias, an adjustment to account for potential risks, uncertainties and unknowns.*

Conclusions

All flood schemes funded through the Welsh Government FCERM Programme must be supported by a business case which demonstrates value for money. NRW have followed the Welsh Government FCERM Business Case Guidance (BCG) in assessing the scheme options and no economically viable (i.e. cost-beneficial) solution has been identified on flood grounds. Sensitivity analyses have been applied in recognition of the significant uncertainties with hydrological data and the costs of either of the short-listed solutions, but neither option is close to being cost beneficial, using current information.

In accordance with FCERM-BCG, the Preferred Option must have a robust economic basis to be awarded Flood Defence Grant in Aid funding. Neither do-something option is economically viable on flood grounds, and neither meet the Critical Success Factors, and so cannot be recommended to proceed to Full Business Case. Should new or refined information become available, then the Business Case could be reviewed and potentially re-evaluated, but as the BCR values are well short of unity (i.e. BCR of 1) then it would take a significant change in cost or benefit information to change the conclusions.

However, importantly, it is also the case that neither the Business As Usual (carry on) or the Walkaway (stop doing anything) options address the high flood risk in the location (and the project's Critical Success Factors), and the problem remains. NRW will continue to work closely with the community, the local authority and Welsh Government to follow through on what else can be done to help manage the risks associated with the watercourse. These considerations however sit outside of this Business Case analysis of NRW's capital scheme options.

Project Details

Project Timeframe	**Start Date:**	30/06/2023	**End Date:**	01/04/2029
Project Name	Ynysybwl Flood Risk Management Project			
BP Code	BP4013			
Directorate	Operations			
Business Board	Flood Risk Management			
Programme (if applicable)	FRM			
Leadership	Operations			
Location (if applicable)	Ynysybwl			
National Grid Reference (if applicable)	ST 05991 94553 (nearest postcode CF37 3LT).			
Place	South Central			

Project Roles	**Name**	**Post Title**
Project Manager	Andrew Basford	Project Manager (PPD)
Project Executive	Mark Groves	Project Executive (PPD)
Budget Manager		Head of Flood & Incident Risk Management
Programme Manager (if applicable)		Manager, Flood Risk Strategic Planning and Investment
Senior Responsible Owner (SRO)		Head of Flood and Incident Risk Management

Senior User (or Expert User Group)		Operations Manager (Flood & Water Management)

Risk Potential Assessment (RPA) Score	Medium
Risk Potential Assessment (RPA) (please provide location / hyperlink here, or indicate if appended to rear)	 RPA Ynysybwl FRMS.xlsx
Project Runway ⓘ	Runway 3
Justification for Project Runway selection	Project total forecast >£2M RPA Medium Risk

Strategic case

Strategic Context

Ynysybwl flood risk management (FRM) project, and as such this business case, is primarily focused on the fluvial (river) flood risk from the Nant Clydach to properties situated on Clydach Terrace, Ynysybwl.

Figure 1: Highway wall on Clydach Terrace (looking upstream)

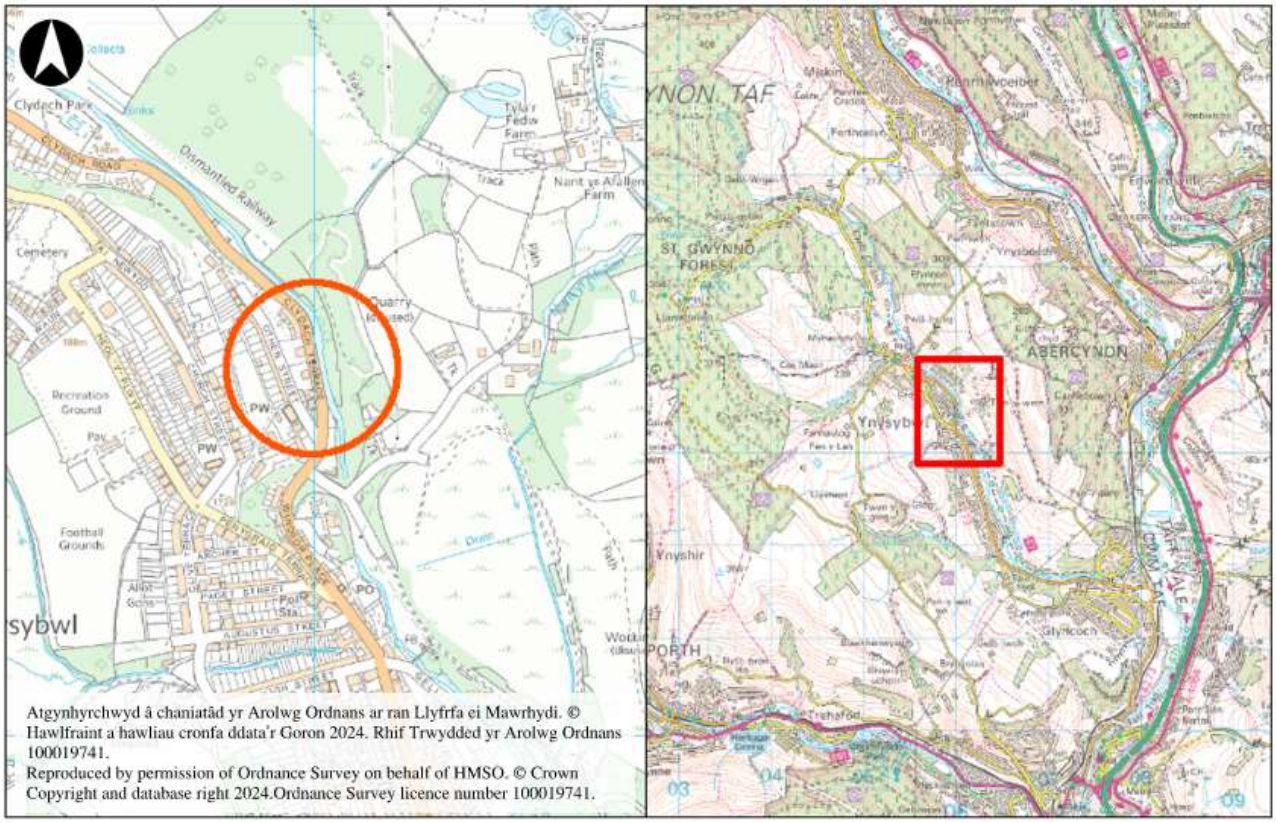

Figure 2: Location Plan; Clydach Terrace

In summary, previous work comprises assessment of flooding and appraisal of FRM measures to determine their feasibility. An options longlist was identified during the Initial Assessment and Strategic Outline Case (SOC). The SOC refined the longlist to a shortlist and undertook an initial high-level economic analysis to indicate whether the shortlisted options have the potential for economic viability.

This Outline Business Case (OBC) has been progressed to further investigate the proposed shortlist. The economic and technical feasibility of the options has been further assessed. This OBC presents the case for formal approval to develop a Full Business Case (FBC), which would detail the final plan to deliver any do-something preferred option. FBCs document the detailed design, the delivery and management plan, confirm funding arrangements, required agreements or consents, and affordability of the preferred option based on market prices obtained during procurement.

Ynysybwl is a village situated in the valley of Clydach, which forms part of the Nant Clydach catchment, which extends approximately 17km^2 upstream. Natural Resources Wales (NRW) manages forestry estate in the catchment above Ynysybwl and the local Forest Resource Plan has been given due consideration for the optioneering. The Nant Clydach, which is classified as a Main River, is a tributary of the River Taff. The watercourse is short and steep, prone to shoaling, and is in a confined upland valley where its course is flanked by residential properties. Clydach Terrace lies on the floodplain in a very constrained section of the valley and has historically suffered from severe flooding from records dating back to 1955. Notably during Storm Dennis on 15th and 16th February 2020, flood waters from the Nant Clydach overtopped the highway wall which runs along the length of the terrace, with records of internal flooding to 16 properties. Flooding was significant with reports that the street was so rapidly inundated with flood water that residents did not have time to respond and the internal flood depths to the lowest lying homes reached 1.96m. Two photographs of the recorded flood depth in this event are provided in Figure 11.

Figure 3: Shoal build-up in the river channel just off of Clydach Terrace

The map below shows the properties flooded during Storm Dennis, along with key features along Nant Clydach.

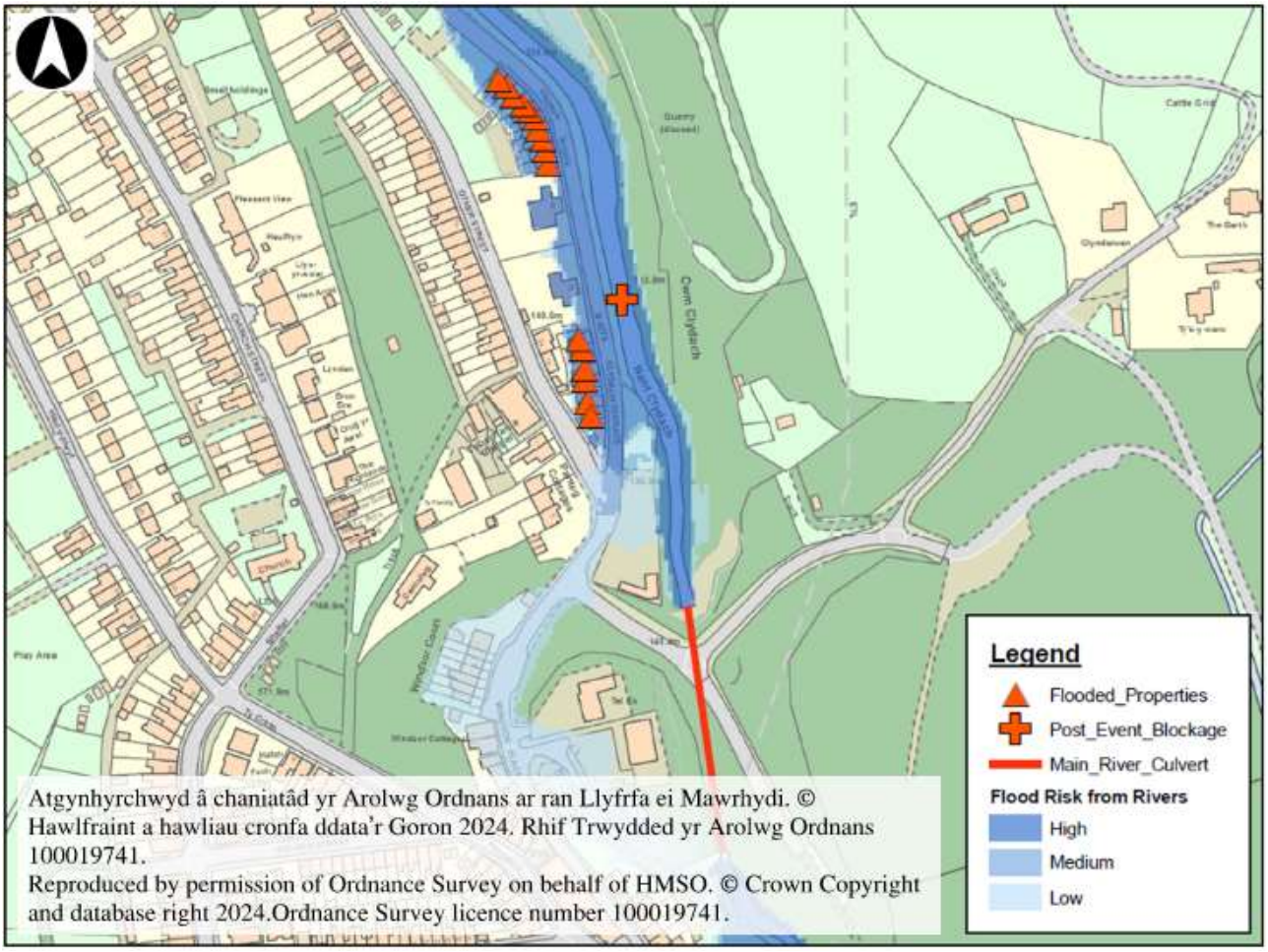

Figure 4: Map of Nant Clydach with reported properties flooded during Storm Dennis (2020)

Flooding also occurred to Clydach Terrace during Storm Bert on the 23rd and 24th November 2024. Two properties were reported to have flooded internally during Storm Bert, and the highway was inundated. Figure 5 shows a photograph looking northwards on the terrace, showing the depth of flooding. The two properties were recorded to have flooded internally to depths up to 50mm. The existing highway wall that separates Clydach Terrace from the Nant Clydach was overtopped opposite the driveways of 6a and 6b on Clydach Terrace and upstream where the footpath steps are located.

Anecdotal reports also highlight that the road becomes spongey during high river flow events. This may indicate that the highway formation becomes saturated either due to groundwater/seepage or linked to the drainage or sewer systems.

Figure 5: Flooding on Clydach Terrace during Storm Bert

Anecdotal information indicated that the existing highway wall leaked in addition to localised overtopping. Photographic evidence supports this, as shown in Figure 6.

Figure 6: Water leaking through the highway wall during Storm Bert

The Nant Clydach is covered by the South Central Flood Risk Management Plan (2024). A key delivery highlight for Ynysybwl in the plan, is to Improve our understanding of flood risk through updates to our flood risk models and analysis of hydrology. In the short term, it states we should undertake an initial assessment and feasibility work for reducing flood risk, investigate feasibility for a new flood warning service and build a hydraulic model.

Following the aftermath of Storm Dennis in 2020, NRW developed a direct rainfall flood model to better understand the flood risk and undertook an Initial Assessment of potential FRM options. No flood studies of the Nant Clydach had previously been undertaken by NRW or its predecessor bodies. The direct rainfall approach used within the modelling study allowed both the fluvial (river) flood risk from the Nant Clydach, and the pluvial (surface water) flood risk to be assessed. The model also assesses residual flood risk of any option, including the impact downstream to properties on Windsor Place and Windsor Court. These issues have been considered in further detail as part of this OBC.

Since publication of the SOC in July 2024, further modelling and economic analysis of the shortlisted options has been undertaken to inform this OBC. The model has been updated to the most recent version of the model software and to represent currently available data. Scheme options and climate change scenarios have been now explicitly modelled, offering the OBC greater detail compared to the SOC.

A 1995 Catchment Management Plan referenced the difficulty in providing a flood warning service at Ynysybwl ‘since the river’s response is too rapid’. It remains that there is no local warning system for the Nant Clydach.

National Strategy for Flood and Coastal Erosion Risk Management

The National Strategy for Flood and Coastal Erosion Risk Management (FCERM) in Wales, as required under the Flood and Water Management Act 2010, sets the framework for managing flood and coastal erosion risks across Wales.

Every FRM action undertaken in Wales must aim to fit with overarching National FCERM Strategy objectives. This assessment contributes to the following objectives:

1. **Improving our understanding and communication of risk**

   A direct rainfall model has been developed, improving the baseline understanding of the level of risk to the local community. Our understanding of the risks has been further developed through the appraisal of FRM options.

   Communication with local residents and wider stakeholders continues to be key to the success of this project. Engagement has continued to be held, advising on the progress to date and timescales for delivery. The project team will maintain the communications plan to inform stakeholders of our findings.

   Rhondda Cynon Taff County Borough Council (RCTCBC) as highways authority and asset owner have supported our understanding of the current condition and residual life of the wall. Post flood event data collection including photographs has been received.

2. Preparedness and building resilience

Currently, there are no formal FRM assets that directly benefit Clydach Terrace or Windsor Place. In addition to this project, NRW has installed a gauge board to allow visual monitoring of river levels. RCTCBC has also installed a CCTV camera looking at the board to allow remote monitoring. An aim of the project is to identify the most viable FRM solution to reduce the risk of flooding.

3. Prioritising investment to the most at-risk communities

Computer river modelling shows that fluvial flooding from the Nant Clydach in Ynysybwl is predicted to directly impact 16 properties on Clydach Terrace in the present day 5% Annual Exceedance Probability (AEP) flood event. This is equivalent to a 1 in 20 chance of flooding in any given year. In larger events, more properties in the wider area are also shown to be at risk of fluvial flooding. The model also indicates that there is a residual risk of surface water flooding in the community. Once the wall overtops, it is not possible to distinguish whether individual flooded properties are specifically affected by fluvial, pluvial risk or both. In total 25 properties are predicted to have been inundated by fluvial and pluvial flooding in the present day 5% AEP event.

NRW's national Communities at Risk Register (CaRR) has been developed to provide an objective means of identifying risk and prioritising FRM activities at a Wales-wide, community level. It allows the level and distribution of flood risk to be quantified across Wales using a standard methodology across all flood sources to calculate a theoretical 'Danger' score. It does so by using outputs from flood models to consider the number of people at risk, the hazard they are exposed to over a range of probabilities, the speed of onset of flooding and their ability to respond in terms of social vulnerability to flooding. It also uses factors such as availability and standard of flood warnings and FRM assets. Ynysybwl ranks 136th on "undefended river" risk, 94th on "managed river" risk in the 2024 CaRR, putting the community in the top 9% of communities at risk of flooding in Wales when considering fluvial flood risk in the current day managed scenario, despite much of the community located outside the Nant Clydach floodplain.

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4. **Preventing more people becoming exposed to risk**

   During the assessment process, the river model was further developed to understand the impact of FRM options to consider if they cause adverse impacts elsewhere. If required, detriment mitigation measures address this issue.

5. **Providing an effective and sustained response to events**

   This OBC has investigated the FRM options shortlisted by the SOC. Meanwhile Risk Management Authorities have formed a multi-agency working group and NFF are supporting Clydach Terrace residents establish a Flood Action Group and a Flood Action Plan.

The latest FCERM strategy incorporates legislation that has been introduced since 2010, that fundamentally influences the approach to FRM in Wales:

- Well-Being of Future Generations (Wales) Act 2015
- Environment (Wales) Act 2016
- Planning (Wales) Act 2015

The Environment (Wales) Act and The Well-being of Future Generations (Wales) Act and Corporate Plan

NRW has a duty under the Well-being of Future Generation (Wales) Act to maximise its contribution to the seven well-being goals, supported by the corporate plan and area statements.

In response to requirements under the Well-being Act and the Environment (Wales) Act, NRW developed Well-Being Objectives to contribute to the delivery of the Well-Being Goals and ensure the principles of SMNR throughout its functions. NRW's Corporate Plan is delivered via NRW Well Being Objectives. The following table provides a summary of project opportunities to align with the Well Being Objectives:

Table 1: NRW Well-being Objectives

NRW Well-being Objective	Example Project Opportunities
Nature is recovering	Take a holistic approach, identifying wider benefits, not just FRM that support community cohesion and resilience, and mental and physical health. Provide enhancement opportunities and consider nature based solutions where viable e.g. natural flood management, building the **resilience of ecosystems.** Achieve biodiversity **net benefit** and provide ecosystems with greater diversity and connectivity. Implement measures to contribute to the control of invasive non-native species (INNS) which are known in the area, pests

NRW Well-being Objective	Example Project Opportunities
	and diseases, where species have widespread negative impacts on the economy, environment and people's health.
Communities are resilient to climate change	Consider the impacts of climate change on flood risk and include flood resilience within the options appraisal assessment. Identify a range of options that consider: land and water issues holistically, recommending management options that maximise SMNR to reap multiple benefits management of flood risk into the future, including allowances for predicted climate change. Water quality and quantity, identifying opportunities that will contribute to their improvement, benefiting both people and ecosystems.
Pollution is minimised	Implement **whole life carbon assessment** as a key performance indicator within the procurement strategy. Engage with **supply chain** early to appraise options that provide resource efficiency and implement where feasible the use of alternative materials.

South Central Wales Area Statement

NRW's 'Area Statements' respond to WG's 2017 Natural Resources Policy, which sets out the key challenges and opportunities for the sustainable management of Wales' natural resources into the future. They outline key challenges facing that locality, what can be done to meet those challenges, and how management of natural resources can be improved for the benefit of future generations.

The South Central Area Statement is dominated by a desire to bridge the urban and the natural environments. It consists of five key themes and sets out to address the legacies of the past along with the challenges and opportunities of the future, exploring ways to work together to protect, value and embrace the natural environment.

Working with Water is a key theme and opportunities overlapping this project include:

- Maintaining, enhancing and restoring floodplains and hydrogeological systems to reduce flood risk and improve water quality and quantity
- Restoring uplands and managing them for biodiversity, carbon, water, flood risk, energy and recreational benefits
- Increasing green infrastructure in and around urban areas
- Reducing the risk of flooding.

Flood Risk Management Plan for Wales: South Central Wales

NRW's Flood Risk Management Plan (FRMP) covers all of Wales and provides information on the scale of flood risk, as well as NRW's priorities for managing the risk of flooding, and the measures it proposes to take, over the coming years. NRW's FRMP covers flooding from rivers, reservoirs and the sea but not flooding from surface water and smaller watercourses. The FRMP fulfills NRW's requirements under Section 25 of the Flood Risk Regulations (2009) but also considers recent fluvial and coastal flooding events and subsequent actions arising from them.

The South Central Wales Area Statement identifies Working with Water as a key theme. The information and proposed actions within the FRMP are directly relevant to this challenge and set out NRWs FRM ambitions to help address it. The South Central Wales Place section provides information about the level of flood risk at a local scale and describes NRW's response. In line with WG's National FCERM Strategy objectives, NRW prioritises and directs efforts to communities at greatest risk of flooding. This uses the CaRR that considers factors (such as the number of people at risk, flood hazard, speed of onset of flooding, social vulnerability and availability of existing FRM measures such as FRM assets and flood warning service). The CaRR is used to inform, plan and prioritise WG's FRM investment programme by targeting the most at-risk communities. Ynysybwl is identified as one of the communities at most risk of flooding in the Area Statement and the following actions are proposed:

- Undertake initial assessment and feasibility work for reducing flood risk
- Investigate feasibility for new flood warning service
- Build hydraulic model

The direct rainfall fluvial model has been built and the SOC published to identify shortlist options to reduce flood risk. This project has built on this by further investigating these shortlist options within the OBC.

The feasibility for a new flood warning service has been reviewed during the Initial Assessment and subsequent SOC and OBC phases of the project. It is not possible to provide a flood warning service for this community that meets the NRW Service Level Agreement (SLA). The alternatives would be either a novel or simplistic approach, but these would come with a risk of excessive false alarms with resulting harm to mental health and 'burn out' from the residents

Local Flood Risk Management Plan: Rhondda Cynon Taff

The Lead Local Flood Authority (RCTCBC) have a remit to consider flood risk from surface water runoff, groundwater and ordinary watercourses. Ynysybwl falls within the Lower Cynon Strategic Flood Risk Area Action Plan. The plan notes that there are no communities in the Lower Cynon that fall within the top 5% (top 111 nationally) of communities at greatest risk of pluvial flooding in Wales but that Ynysybwl is the highest community at risk of pluvial flooding in Lower Cynon (ranked 177th).

The Plan includes the action: "Clydach Terrace FAS (Main River Flooding) - *The Lead Local Flood Authority (LLFA) will cooperate with NRW as the RMA for main river flooding who are*

leading on the development of a business case to manage the risk of main river flooding. (ref SFRA8 A4)".

The Council's revised Local Flood Risk Management Strategy and Action Plan[3] was approved by Cabinet on 24th January 2024 and received Ministerial approval from the WG in December 2024.

Objectives ⓘ

The key Ynysybwl FRM project objectives were agreed with the project team as provided in Table 2. There is potential scope for additional wellbeing and environmental enhancements aside from the management of flood risk, which is included in Table 36 – Project Products.

Table 2: Project Objectives

SMART	Objective description	Indicator	Timescale
1	Reduce flood risk to properties at Clydach Terrace given the current absence of flood defence assets.	Achieved once preferred option reduced the risk of flooding to the residents is in operation.	Implementation of the potential preferred option is expected to be delivered by 2029.
2	Minimise long term FRM maintenance requirements whilst also avoiding service failure.	Achieved once long term maintenance costs reduce and the current SoP is maintained or improved.	Implementation of the potential preferred option is expected to be delivered by 2029.
3	Contribute to the well-being objectives (NRW Well-being statement and the SCW Area Statement)	Achieved once preferred option shows positive contribution to the well-being objectives.	Implementation of the potential preferred option is expected to be delivered by 2029.
4	Embed SMNR principles in ways of working and contribute to maintain and/or enhance biodiversity and identify wider opportunities for ecosystem resilience.	Achieved once the assessment of the potential preferred option shows positive contribution	Implementation of the potential preferred option is expected to be delivered by 2029.

[3] Rhondda Cynon Taf County Borough Council, February 2025 – Flood and Water Management Act 2010 Local Flood Risk Management Strategy and Action Plan (https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/FloodAlleviation/FloodRiskManagement/LocalFloodRiskManagementStrategy.aspx)

		to the NRW's Well-Being Objectives.	

Existing Arrangements

NRW currently has no FRM assets in Ynysybwl. The 1.2m high existing highway wall running along Clydach Terrace potentially acts as a de facto FRM asset, even though its original design/purpose may not have been so. The construction and long-term performance of the highway asset as an appropriate FRM asset is not known.

The wall is owned and maintained by RCTCBC highways authority who have conducted a structural assessment of the wall to determine its condition following Storm Dennis. The findings from the assessment have not been shared with NRW or with residents directly. The ongoing maintenance of this structure will need to be considered further with RCTCBC.

During Storm Bert, water was shown to be leaking through the highway wall. A walkover in January 2025 observed that there are multiple cracks in the wall and areas where the render has failed, exposing the brickwork beneath. A summary of observations of the wall made on site is presented in Figure 7.

Figure 7: Summary of observations of the RCTCBC highway wall made in January 2025

The extent of failed rendering appears to have increased since 2022, particularly along the northern section of the wall, and several signs of cracking within the wall were also observed. The assessment indicates that the wall condition may be deteriorating. The expected residual life of the wall is not currently known.

Information gathered in the aftermath of Storm Dennis in February 2020, indicated that prior to overtopping of the highway wall, Clydach Terrace was already experiencing flooding which was assumed to be from surface water. Residents suggested to NRW that the

highway wall first overtopped at the downstream end of the street. Anecdotal information obtained during Storm Bert in November 2024 mentioned that in addition to flooding caused by overtopping of the highway wall, the wall was also outflanked at the southern end. This mechanism of flooding is not well understood or well recreated within the hydraulic model.

The river is prone to shoaling which reduces the channel capacity which is likely impacting flood risk. NRW and its predecessor bodies have maintained the channel through removing shoal accumulations. Around 500 tonnes of river shoal material was removed from the channel adjacent to Clydach Terrace, as shown below, in July 2020. This work was repeated more recently in March 2023, where a further 220 tonnes of material was removed from the riverbed. Shoal levels are monitored by NRW's Integrated Engineering Team against an agreed trigger level.

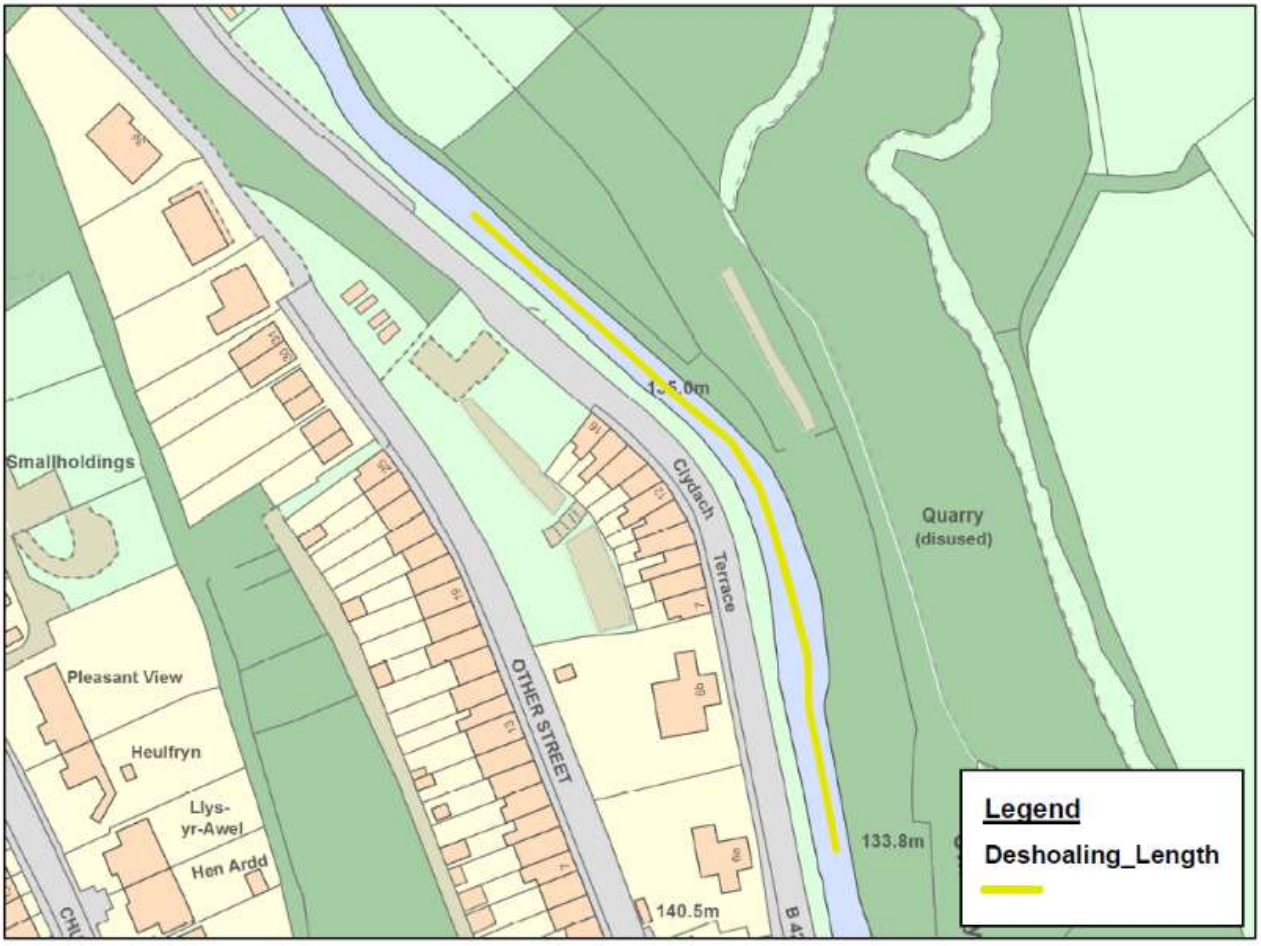


Figure 8: De-shoaling length within the Nant Clydach

A number of residents have signed up for a Flood Alert for the nearby River Cynon, under the assumption that raised water levels in the adjacent catchment may be an indicator of raised levels in the Nant Clydach. Whilst this may give warning of the potential of elevated levels, it is likely some events will go without any form of warning. In addition to this, a local gauge board adjacent to the watercourse remains in place.

Local drainage systems also appear to be overwhelmed during periods of moderate rainfall, with local reports that they are subject to surcharging causing problems of their own.

Demountable flood gates have been supplied to individual properties by RCTCBC to mitigate this risk.

Multi-Agency meetings with residents have been valuable at gathering detailed information on the nature and details of flood events, and advice has been shared. A community Flood Response Plan is being co-created and the National Flood Forum (NFF) is providing support. Property Flood Resilience (PFR) measures such as demountable flood gates have been actively offered to all residents at each Multi-Agency meeting.

On 22nd January 2025, it was discovered that unknown third-party(s) felled a section of trees on the western bank of the Nant Clydach (see **Error! Reference source not found.**). This occurred with no prior knowledge or involvement from NRW. The approximate extent of felling is shown below.

The felling is not expected to have a significant impact on flood risk, but it may reduce potential risk of channel and culvert blockage from fallen trees. It may also result in accelerated erosion of the river bank, leading to increased sediment loading of the watercourse and pose an addition risk to the adjacent highway wall.

The environmental baseline was established prior to the felling. The felling will be considered during preparation of the Net Benefit for Biodiversity Appraisal (NBBA) if a scheme is presented to the Planning Authority.

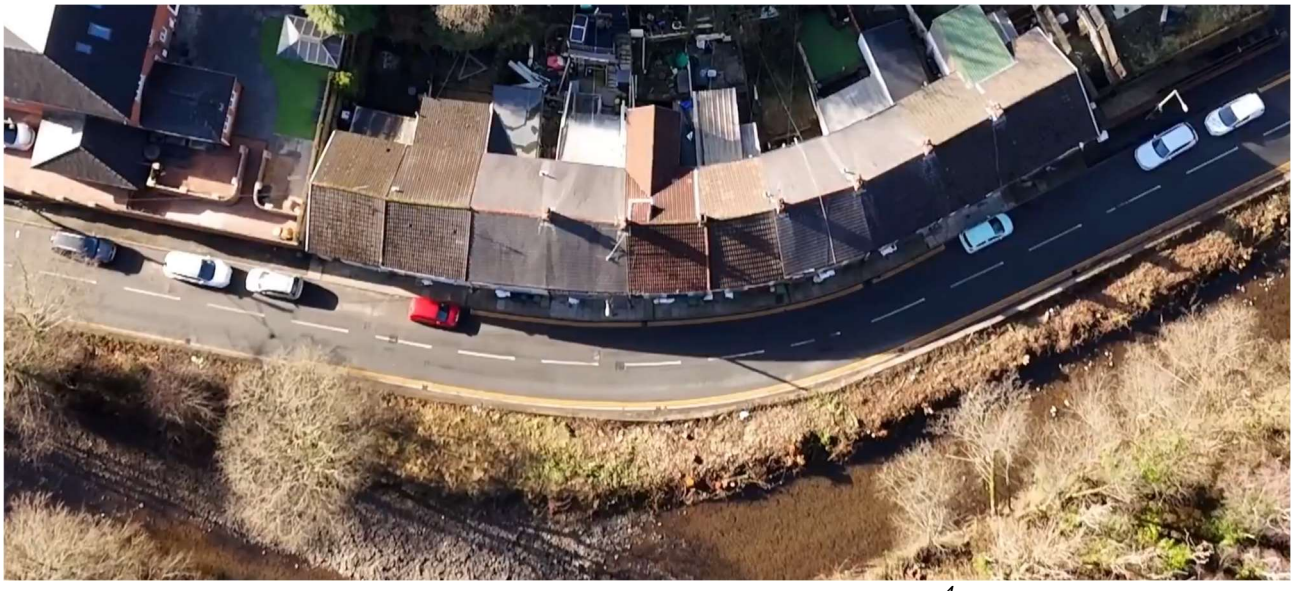


Figure 9: Aerial footage showing extent of tree felling by third parties (Source: Channel 4[4])

[4] Wales flood: residents living in fear years after Storm Dennis – Channel 4 News, accessed 28/03/2025

Figure 10: Image of Nant Clydach from the northern extent of the wall looking southward after felling (12/02/2025)

In March 2025, RCTCBC installed a CCTV camera at the entrance to the Nant Clydach tunnel downstream to remotely inspect for potential blockages during high river flows to aid operational decision-making.

Need / Opportunity

The most recent severe flood events were during Storm Dennis in February 2020, resulting in internal flooding to 16 properties, and Storm Bert in November 2024 resulting in internal flooding to 2 properties. Records dating back to 1955, show periodic flooding within the area. A summary of the events are listed in the table below, noting the properties affected and impact recorded.

Table 3: Flood History

Date	Properties Affected	Additional Comments
1955	Unknown	6th & 7th June 1955. River flooding of properties and highway. JBATrust data – British Chronology of Flash Floods indicates that a heavy short duration rainfall event occurred on the 6th June 1955. • Pontypridd – 2.92in 40mins (74mm) • Merthyr Tydfil – 1.5in 96mins (38mm) At Ynysybwl: • Rain flooded many houses up to the ground floor ceilings. Many residents had to be rescued from upstairs rooms. The road to Pontypridd was blocked by a landslide.

1960	1	4th December 1960. River flooding of highway, 1 public house. The following rainfall totals were recorded on 3rd December 1960. • Mountain Ash – 5.43in / 137mm. • Clydach Reservoir – 5.4in / 135mm. Records show the Mountain Ash gauge recorded 17.52in / 445mm for the previous month (November 1960).
1979	2	27th December 1979. No7 & No8 Clydach Terrace. Flooded due to river level restricting operation of drains. (Surface Water)
1998	Nil	22nd to 31st October 1998. No property flooding. Highway was flooded from surface water and potential overtopping from main river.
2020	16	16th Feb 2020 (Storm Dennis). Flood depths ranged from 300mm to 1.9m. No River Telemetry available for this catchment. However, Nant yr Ysfa rain gauge recorded 130.4mm in the 24hrs leading up to 7am 16th February 2020. This equates to 72% of February LTA rainfall at this location. Initial hydrology estimates this to be around 1in30yr rainfall event.
2024	2	24th November 2024 (Storm Bert). The existing highway wall that separates Clydach Terrace from Nant Clydach, was overtopped. Photos from this event indicates that the existing highway wall leaked in addition to localised overtopping. Residents highlighted that the wall overtopped opposite the driveways of 6a and 6b on Clydach Terrace and upstream where the footpath and steps are located. A clear wrack mark was observed along the bank top next to the wall with <0.3m freeboard along most of the wall. Anecdotal comments suggest the road had been spongey during high river flow events, indicating that formation may become saturated during such events.

Following the aftermath of Storm Dennis, NRW undertook post flood event investigations which included a threshold level survey at properties impacted and the survey of a wrack mark from Storm Dennis at No7 Clydach Terrace:

- Property Threshold Level – 134.027m AOD
- Storm Dennis Wrack Mark – 135.988m AOD
- Storm Dennis Observed Depth – 1.96m

The two photographs shown in Figure 11 below indicate the recorded flood depths at Clydach Terrace. These illustrate the significant danger posed by the flooding during Storm Dennis.

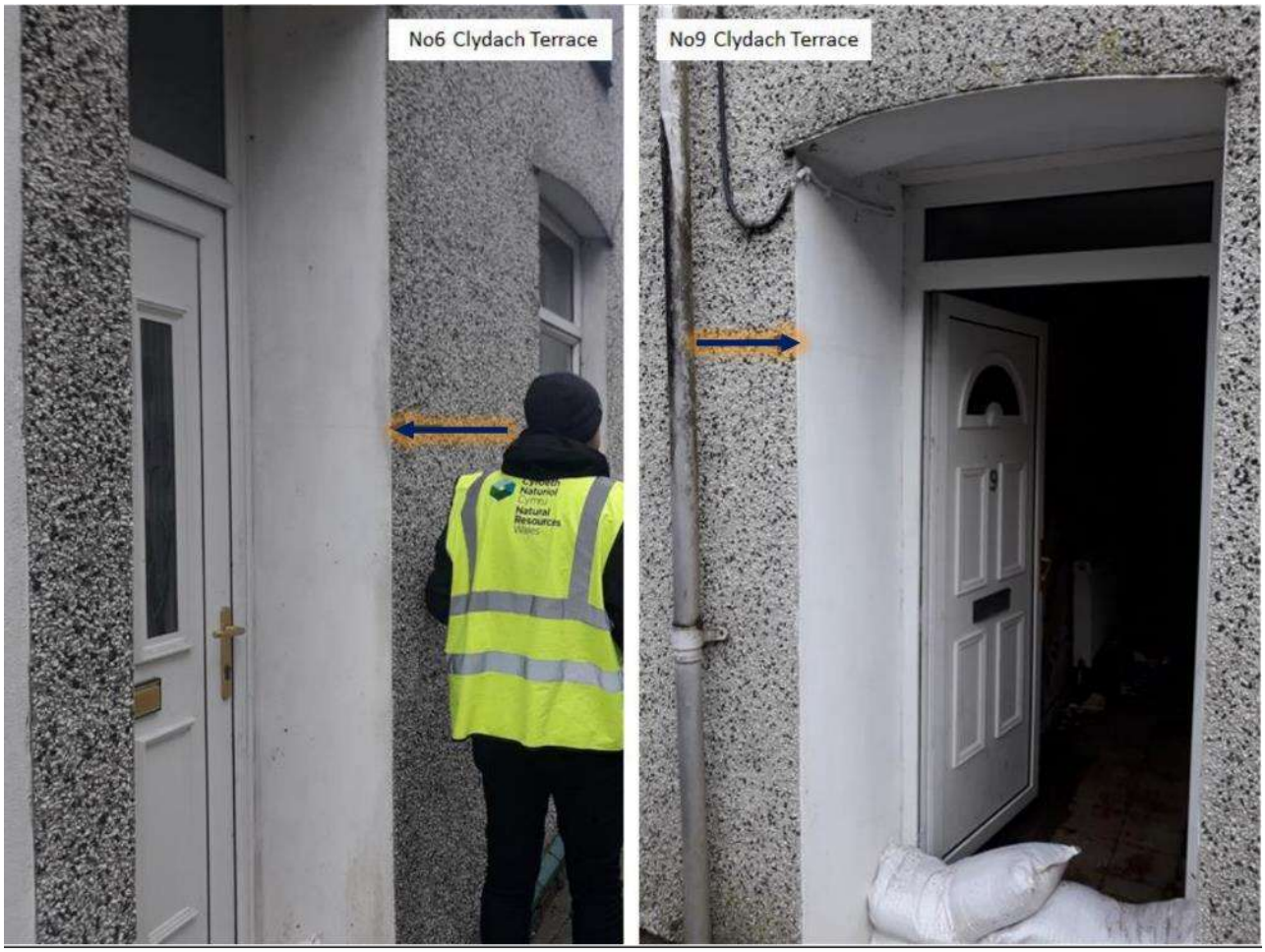


Figure 11: Height of flooding observed at two properties on Clydach Terrace during Storm Dennis

Scope

The primary focus of the project is to reduce fluvial flood risk to properties at Clydach Terrace.

This OBC will further investigate the shortlisted options appraised in the SOC to establish viable options for reducing fluvial flood risk arising from the Nant Clydach. The scope of this OBC has included consideration of the properties along Windsor Place and Windsor Court, should further investigations identify these properties as being at flood risk in the Business As Usual (BAU) scenario or at detriment due to any proposed actions and pluvial flood risk, working in partnership with RCTCBC.

The following factors have been considered during the project:

Study Area: The project study area primarily focuses on properties along Clydach Terrace. However, FRM options have been considered throughout the Nant Clydach catchment.

Landowners, stakeholders and public support: The delivery of a successful FRM project relies on the broad support from stakeholders. Landowner compensation and/or purchase of land may be required. NRW's SMNR principles, applied throughout this project, promote

collaboration, stakeholder and public participation, and reinforce collaboration and cooperation for key decisions. The OBC has followed a Communications Plan prepared and managed by NRW to identify, understand, and engage with key landowners, stakeholders, and the wider local community.

Hydraulic modelling updates and Residual Uncertainty Analysis

A hydraulic model of the Nant Clydach and catchment has been used to assess flood risk and economic damages within the study area. This model was originally produced in 2022 and comprises a linked 1D-2D ESTRY-TUFLOW model. The model uses a direct rainfall approach in order to explicitly represent the flow routing in the upper catchment. Due to the direct rainfall approach, the model is able to assess flood risk from both fluvial and pluvial sources. Prior to the onset of the OBC modelling work, minor updates were made to the hydraulic model, including:

- TUFLOW software updated to the latest available version (2023-03-AF-iSP-w64);
- The threshold level of a building at the southern end of Clydach Terrace was corrected to 135.025mAOD, as it was previously input as 134.025mAOD

The updated model supported a more detailed modelling exercise for the wall option to ascertain the required wall height to provide the scheme SoP, and also for the purchase by agreement option in combination with WAW assumptions. The BAU, WAW and both option scenarios were also run for required return periods and climate change allowances to assess the change in flood risk over the appraisal period.

A comparison exercise between the flooding observed in Storm Bert and the new model outputs was not required. The model has been verified previously against Storm Dennis, and the flooding observed in Storm Bert is consistent with that predicted by the model, with the highway wall overtopping in low order events and flooding to properties on Clydach Terrace.

Industry-standard Residual Uncertainty Analysis (RUA) has identified a significant freeboard is required to provide confidence in the Standard of Protection (SoP) provided by a raised defence or wall option. The study has followed the most recently available guidance, Assessment of Residual Uncertainty - Supplementary Technical Guidance (LIT 73536)[5] produced by the Environment Agency. The RUA has highlighted that there is significant uncertainty in the input rainfall, associated with the lack of gauge data in the catchment and the impact of antecedent conditions on the flows within the Nant Clydach. The large amount of uncertainty in this parameter results in a significant freeboard being required to provide confidence in the design SoP for the wall. The assessment also indicated that, even if gauge data were to be collected over several years, it is likely that the uncertainty in the input rainfall would remain high.

[5] Assessment of Residual Uncertainty - Supplementary Technical Guidance (LIT 73536), Environment Agency *April 2024*

Updated economic analysis

An updated economic analysis at OBC has further refined the assessment undertaken at SOC stage. The OBC assessment has used the latest available Multi-Coloured Manual (MCM) and Greenbook guidance to assess flood damages and benefits from a range of sources including: damages to residential and non-residential properties, emergency services costs, mental health costs, evacuation and temporary accommodation costs, risk to life, vehicle damages and intangible benefits to health.

The updated economic analysis has indicated that none of the shortlisted options have a BCR that is less than unity. This is in contrast to the SOC analysis, which indicated that the wall option could have a Benefit Cost Ratio (BCR) of 1.4 and the purchase by agreement a BCR of 0.5. The reduction in the Present Value Benefits (PVb) has been attributed largely to the high-level economic assessment that was undertaken at SOC using the WG Rapid Assessment of Damages (RAD) tool, which makes assumptions and simplifications in the appraisal methodology when compared to the more detailed study for this OBC.

This analysis was undertaken concurrently with the RUA assessment, so an interim assumption was made for the required freeboard for the wall option. The completed RUA assessment indicates that this is likely to be too low. The costs of this option are therefore likely to be higher than presented, and the BCR will be lower.

Environmental impacts (SOC Stage): A Preliminary Ecological Appraisal (PEA), Preliminary Water Environment Regulations Compliance Assessment (WFD), and a Strategic Environmental Review (SER) were produced as part of the SOC. The reporting identified potential environmental impacts and potential opportunities for environmental improvement, associated with each option. These would be incorporated into planning and delivery, and realised upon completion, to maximise the contribution to NRW's Well Being Objectives.

The PEA report conducted as part of the SOC has identified Sites of Special Scientific Interest (SSSI) and Sites of Importance for Nature Conservation (SINCs), as well as protected and notable species within the study area.

The WFD report identified the potential for beneficial effects to fish, potentially resulting in water body scale improvements which could contribute to the water body attaining Good Ecological Status by 2027. There was insufficient information to understand the full potential for benefit. There is potential that the rock tunnel is the primary driver for the WFD status of moderate for fish, the only quality element that is preventing the water body from attaining Good status. The project should consider the potential to include modifications to the flow conditions through the rock tunnel to improve fish passage. This may be sufficient to allow the WFD water body attaining Good Ecological Status.

The SER states the study area falls within Clydach SINC, Lower Clydach Woodlands SINC, and Y Ffrywd SINC. These SINCs form a complex mosaic of habitats, linked by the valley of the Nant Clydach.

The SER identifies that as part of the Ynysybwl FRM project, there are potential opportunities to improve biodiversity and resilience of ecosystems, land management, soil

management, improve or enhance the WFD status of the Nant Clydach and landscape and visual amenity. The opportunities or constraints from an environmental perspective are dependent on the options progressed in this OBC stage.

The SOC identified potential environmental impacts associated with the longlisted and shortlisted options. In particular, hydrological disruption, an increase in air, water, and/or noise pollution, visual or vibrational disturbance during construction and/or operation, and habitat loss/disruption. Further information regarding the specific environmental and ecological impacts and constraints for each of the longlisted options is provided in the Longlist Options Appraisal, appended in the Products Section of this report.

Suitable mitigation, and where not possible, compensation measures would be identified through the environmental appraisal process, in addition to opportunities for environmental and social enhancements. Consequently, it is considered that the potential environmental impacts can be appropriately managed for the project options and do not represent a major risk, constraint, or dependency. Opportunities also exist to fulfil SMNR project objectives through the environmental and social enhancement opportunities.

Environmental impacts (OBC Stage):

During this OBC stage, an Environmental Scoping Report (ESR) has been produced. This ESR contains the environmental baseline for relevant topics: Population, Biodiversity, Water, Cultural Heritage, and Landscape, including aspirations and challenges. This report would be updated after a potential recommended preferred option(s) is identified and the project proceeds to FBC, to include an environmental assessment screening and scoping, and potential enhancements. This report is accompanied by a set of Environmental Constraints and Opportunities Plans.

Further, a NBBA has been produced to support the optioneering stage of this OBC. This relates to the option of construction of a flood wall, namely through calculating habitat baseline extents within the area of interest and potential loss of habitats and the likely minimum habitat compensation/replacement targets informed by existing guidance's and requirements such as Planning Policy Wales 12 (PPW12), Local Planning Authorities Supplementary Planning Guidance (SPG), and requirements relating to protected species potential present on site. Further it provides high-level advice on potential opportunities for habitat retention, creation and enhancement for the proposed development area (whether on site or offsite), in line with nature conservation policy, legislation and guidance and the stepwise approach.

Whilst detail on potential opportunities considers the DECCA framework (Diversity, Extent, Condition, Connectivity and 'Aspects' of ecosystem resilience) as described in PPW12 and NRW's guidance, a full assessment of how DECCA, and therefore Net Benefit for Biodiversity (NBB) and ecosystem resilience has not been undertaken, in the absence of full scheme details. All schemes applying for planning permission must demonstrate they have achieved a NBB and enhanced ecosystem resilience through applying a Stepwise Approach by avoiding, minimising or mitigating likely significant effects.

To inform the environmental baseline conditions, initial ecological surveys covering bats, dormice and otter were completed in late 2024. Further, arboricultural surveys have reported on tree numbers and initial health, with a return visit following the tree felling in 2025.

In respect of otter and dormice, due to the small survey window at the end of the 2024 season, although no conclusive evidence of otter or dormouse were found, further surveys were recommended surveys to allow conclusions to be supported by best-practice methodology.

In respect of the bat surveys, 27 buildings were assessed as having suitability to support roosting bats, 8 trees found with potential roost features that would require a close inspection (via rope access, Mobile Elevating Work Platform or ladder) to determine their suitability to support roosting bats. Once a preferred scheme is proposed, discussion with an ecologist regarding buildings/trees that may be impacted and requirements for further survey for the presence of roosting bats.

In respect of the trees, the study area consists of an area of Restored Ancient Woodland (RAW) covering both banks of the Afon Clydach. The western bank is a strip of riparian ground between the river and highway wall which runs alongside the length of Clydach Terrace. Within this, the canopies of the larger mature trees overhang the highway. The trees consist of naturally regenerated mature and early mature trees lining the river bank consisting predominantly of alder with occasional birch, sycamore, ash and goat willow. The larger mature trees were classified as retention category 'B' trees of moderate value whereas the poorer/younger specimens were category 'C' trees of low value.

The original arboricultural survey was conducted on 26th September 2024 to assess the existing trees in terms of health, condition, form and overall significance within the local environment, the main objective being to assess the degree of constraint they represent with regard to the proposed redevelopment of the site. The site was resurveyed on 3rd March 2025 following reports that trees had been removed and stumps treated with herbicide to ensure there would be no regrowth. A total of 43no. category 'C' trees and 1no. category 'U' tree had been removed by comparing survey results.

In terms of the tree's felled and planning policy guidance, PPW12 states: "*Where a site has been cleared prior to development its biodiversity value should be deemed to have been as it was before any site investigations or clearance took place. A net benefit for biodiversity must be achieved from that point. Habitat status can be established through evidence remaining on site and local desk based assessments … In such cases, habitat status will be presumed to be good in the absence of any evidence to the contrary.*"

Assessments assume the biodiversity value prior to felling, based on good condition woodland if evidence demonstrating otherwise is absent. Data already collected, soil sampling, and condition assessments of the adjacent woodland parcel may inform this prior condition. Details of any potential felling licence in terms of any re-stocking plans would support future iterations of the OBC evidence base i.e. considering the 'future baseline of the site'. Equally given trees were flagged in this area as having moderate suitability to support bat roosts, details of mitigation requirements applied separately under that permit to offset should be factored into future project stages.

Health & Well-Being: The existing threat of fluvial flooding during a flood event is detrimental to the health and well-being of the residents. Flood risk mitigation measures typically improve mental and physical health, by reducing the ongoing fear and worry related to flooding. There is also the potential for wider community health and well-being benefits. Any detrimental impacts of the project to health and well-being would also need to be considered; it is noted in this case that there is likely to be mental health impacts associated

with a hard defence option, due to the residual risk of overtopping and the proximity of the defence to resident's properties. Additionally, if no intervention is pursued, the risk rating for public health and well-being must be updated to 'Major,' reflecting the high levels of deprivation in the area and the significant threats posed to residents' safety, resilience, and long-term welfare.

An EqIA report has been produced to better understand the specific positive or negative impacts of the longlisted and shortlisted options on those people who have a protected characteristic. The EqIA would be further updated following selection of preferred option. At that point, specific actions for mitigating any adverse impacts would be identified. Further information regarding the positives and negatives of each of the longlisted options is provided in the Longlist Options Appraisal found in Table 9.

Archaeology & Heritage: Ynysybwl is located within NRW's Nant Clydach Landmap historic landscape area. This area, which also includes the settlement of Glyncoch located approximately 2km south-east of the study area, is defined and dominated by the former coal mining industry of the late 19th Century and 20th Century.

One designated heritage asset has been identified in the study area; Ynysybwl War Memorial. It is designated a Grade II listed building and is located approximately 220m south of the site.

There are no World Heritage Sites, Grade I and Grade II* listed buildings, registered historic park and gardens of any grade, registered battlefields, or conservation areas within the study area. There are no Registered Historic Landscapes in proximity to the study area. Thirteen recorded non-designated heritage assets have been identified throughout the study area; none of which are located within the site. The closest to the site, located approximately 50m to its west, is Tabernacle Welsh Independent Chapel, Ynys-y-Bwlare.

The remaining non-designated heritage assets are predominantly historic buildings. Most are churches or chapels, which were founded at the same time as the town itself during the late 19th Century. The site of the former Lady Windsor Colliery which was in operation from 1885 to 1988 and was the impetus for construction of Ynysybwl is also recorded but has now been reclaimed.

Both shortlisted options could provide enhancements to the interpretation and communication of Ynysybwl and its community's mining heritage and identity through, for example:

- the inclusion of design elements such as in-situ physical interpretation;
- interaction with, and the incorporation of, existing heritage initiatives such as trails, exhibitions, or public installations; or
- other community-driven cultural or heritage projects.

Geomorphology

A Geomorphology walkover survey has been undertaken, along with desk-based analysis of the river's long section and erosive energy (specific stream power).

Overall the erosive energy of the Nant Clydach is high, with readily transportable bed material and significant sediment sources from the steep riverbanks. The watercourse is relatively short and steep with little to no floodplain.

The long-section analysis notes that the gradient of the Nant Clydach alongside Clydach Terrace is shallower than upstream and downstream, which corresponds with survey evidence which noted transient sediment storage in this reach. De-shoaling works have been completed by NRW in this reach in recent years.

The walkover survey identified four distinct geomorphic reaches through the study area:

- Reach 1 being upstream of Clydach Terrace, where the river in incised with high energy and some bedrock outcrops. A significant supply of coarse sediment was evident.
- Reach 2 is lower energy and alongside Clydach Terrace. Alternate bars providing transient sediment storage were noted.
- Reach 3 is the rock tunnel, created in the late 1800's to divert the river to accommodate mining activities.
- Reach 4 is downstream of the rock tunnel. The river flows within a much steeper, gorge-like valley at this point, with a largely bedrock substrate.

Landscape and visual

The steep wooded valley side to the east and the terraced hillside settlement to the west create an enclosed visual envelope from within which views of the scheme can be experienced. Views out from the proposed scheme are contained within the valley. Views to the east are foreshortened by vegetation coverage along the lower slopes of the valley. Views to the west are foreshortened by the residential dwellings along Clydach Terrace.

Medium length views are oriented north-south along the valley floor. However, the existing flood wall structure along the B4273 interrupts these views. Longer range views to the surrounding hill tops are glimpsed and heavily filtered through intervening woodland, which forms a backdrop to the settlement of Ynysybwl. These limited visual connections between the urbanised valley floor and the wilder upland plateaux are characteristic features of the local townscape.

Wider views from the surrounding hills looking down towards the proposed scheme are obscured by intervening woodland and built form further down the valley sides .

Potential changes in views are only likely to be experienced within close proximity of the proposed scheme. Footpaths in the surrounding landscape do not offer views of the river corridor due to intervening woodland. The valley floor forms a small part of expansive and far-reaching views available from the surrounding higher ground.

Identified visual receptors include:

The community living along Clydach Terrace

This community would be impacted by the proposed changes to their views of the river. For those residing on Clydach Terrace, these are likely to be prominent and uninterrupted changes in views due to the proximity of the higher flood wall. These residential receptors are sensitive to the type of change proposed. Properties on Clydach Terrace obscure eastward views of the proposed development from residents living on the terraces further to the west.

Road users on Clydach Terrace (B4273)

Road users here would also experience changes in views. These receptors are less susceptible to changes in their views as their primary focus is on driving. Therefore, they are of low sensitivity to the type of change proposed.

The proposed scheme is constrained by the Nant Clydach and the existing B4273 road, preventing the wall alignment to be positioned further from the properties. This also limits opportunities for mitigation planting to help filter or break up views of the flood wall for the community along Clydach Terrace. Given the height of the proposed scheme, tree planting behind the wall is unlikely to effectively mitigate any visual impacts.

Geotechnical

A geotechnical desk based study including site walkover has informed a better understanding various constraints in the study area.

UXO risk maps indicate that the site is in a low-risk area for unexploded ordnance, with no features identified within the site boundary or surrounding area.

The Coal Authority mapping (The Coal Authority n.d.) shows multiple mine entries approximately 300m southeast of the site, possibly linked to the Lady Windsor Colliery and the site does not lie in a high-risk area for development.

There was historically a mineral railway, on the east side of Nant Clydach and another railway impinges close to the southern section of the highway wall. It is possible that made ground associated with these railways may be encountered during the works. This made ground may contain contaminants related to railways which include metals, hydrocarbon, asbestos and general inorganic contamination.

Whilst no other obvious significant sources of contamination have been identified from historical records in the immediate vicinity of the highway wall, there is a risk that contaminated Made Ground materials may be encountered during the replacement of the existing wall, as well as that associated with the railways. Made Ground of unknown origin can be a source of metals, hydrocarbon, asbestos and general inorganic contamination.

From the site walkover, shallow bedrock and made ground are anticipated to be present on site. These were considered as part of design development, particularly considerations around constructability due to likely difficult excavation, variations in rockhead level and conditions across site and potential limitations on re-use of site-won materials on site.

Constraints and Exclusions

Nant Clydach adjacent to Clydach Terrace is a designated Site of Importance for Nature Conservation (SINC). This highlights its ecological significance, where the conservation of flora, fauna and other features is deemed important. The designation as a SINC implies that the site holds ecological value, and any actions taken within the area would consider avoidance of potential negative impact on the environment, and should this not be possible, then appropriate mitigation would be implemented. There are no SSSI or Special Areas of Conservation (SAC) in the immediate vicinity of the properties, however there are in the wider study area. These would need to be considered should FRM options that interact with these designations show potential.

Permissions and consents: Permissions and consents would be required to deliver any potential option. This may include Environmental Impact Assessment (EIA) screening in accordance with the Town and Country Planning (EIA) (Wales) Regulations 2017, planning permission, Flood Risk Activity Permit(s), SAB approval and protected species licences.

Within this OBC, the option of purchase by agreement is considered among other engineering solutions to reduce flood risk in Ynysybwl. The purchase of property for the management of flood risk is a novel approach and, as such, there is currently no policy or process to readily support it. Approval and funding of any FRM option is subject to agreement of WG with NRW setting out the basis of any suggested acquisition for Ministers' consideration. NRW could exercise its compulsory purchase powers (CPO) or at least work within the same principles if agreements with homeowners were reached outside of the CPO process, which would mean that any acquisition would be made in line with the relevant legislation and compensation code. The underlying principle of any acquisition in these circumstances, and enshrined in the compensation code, is one of 'equivalence' with no party affected by acquisition better or worse off through consideration of appropriate market value of properties affected. NRW is not privy to nor has influence over any contractual arrangement between a landlord and tenant, however the underlying principle remains.

Utilities: Utilities are located in proximity to the shortlist options. The presence of this infrastructure is a potential constraint on any potential construction methodology and permanent works.

A utilities desktop records search in January 2024 identified the following:

- BT cable and poles on Clydach Terrace, immediately behind the existing highway wall on the retained side;
- LV overhead lines along the houses and along the existing highway wall on Clydach Terrace and the south extent of the site and underground HV (11kV) crossing underneath the wall and on the retained side of the existing highway wall by National Grid Electricity Mapping (NGED) mapping;
- 2 No combined sewers, crossing under the existing highway wall and on the retained side of the existing highway wall between the highway wall and Nant Clydach;
- Existing Welsh Water distribution main and fire hydrant, west of the existing highway wall on Clydach Terrace;
- Low pressure (LP) 21 mbar – 75mbar pipe, west of the existing highway wall on Clydach Terrace.

Dependencies ⓘ

To successfully deliver the project objectives, requirements from other programmes as well as Forestry (see Forest Resource Plan), such as FRM maintenance, or parties, such as the LLFA, would be considered.

Obtaining permits or consents for working in water bodies, activities related to highways, and complying with regulations related to protected species would be necessary for works to commence.

Collaboration with RCTCBC to align any existing highway drainage maintenance plans with the project activities to ensure the effectiveness and integration of the preferred option to any existing plans.

There may be scope for the emerging Taff Catchment: Strategic Management Plan to influence the project depending on its findings and recommendations, however that work is in early stages, and due to the political and public implications of Clydach Terrace, this project cannot allow for time to wait for the Taff Strategy findings. Additionally, the Taff strategy is focused on improving understanding of interdependencies and finding solutions to more complex flooding mechanisms within the catchment; by contrast, Ynysybwl is on a tributary with limited interaction with other flood risk locations. It's therefore unlikely to provide notable insights or additional options for this community.

Legal support (within NRW and possibly independent external solicitors) would be required for any potential option involving property purchase by agreement.

Benefits

Projects deliver products which are used to bring about business change. The outcomes are the change brought about by using the project products. The benefit is the measurable improvement resulting from the outcome.

The FRM project in Ynysybwl aims to reduce the flood risk to the 16 properties on Clydach Terrace, which flooded during Storm Dennis, and potentially the wider community such as Windsor Place. The project seeks to reduce the current flood risk and act to mitigate the increasing future flood risk as a result of climate change.

Further, there may be opportunities to provide environmental benefits, including those which promote biodiversity and improve the natural environment. A potential benefit of the project is the reduction in long term operational expenditure and resource demand. The benefits of the project are summarised in Table 4.

Table 4: Benefits of the Project

Benefit Description	Benefit Owner
Reduced fluvial flood risk for the 16 properties at risk of flooding at Clydach terrace	Tim England – Operations Manager (Flood & Water Management)
Reduced long term OPEX costs and resource demand	Tim England – Operations Manager (Flood & Water Management) Aneurin Cox – Operations Manager (Land & Assets)
Achieve Biodiversity net benefit	Tim England – Operations Manager (Flood & Water Management)

Risks

High-level delivery risks are summarised in Table 5. The project risk register has continued to be developed and managed during the OBC stage and will be reviewed at key milestones throughout the project lifecycle.

Table 5: Summary of Project Risks

No	Key Project Risk	Mitigation Plans
1	Detriment (including flood risk and environmental) which cannot be mitigated results in objections to licenses and permits	Design mitigation for detriment caused. Early consultation with property owners affected to assess likelihood of avoiding objections. Early consultation with NRW FRA team. Modelling assessed the flood detriment of the shortlisted options. This would inform any future Flood Consequence Assessment (FCA) and support consenting in the detailed design phase of works, prior to submitting the Full Business Case (FBC) and requesting approval for delivery.
2	Insufficient funds – WG Grant in Aid, and Risk Management Authority partnership funding	The project business case will be submitted to the PMO and FRM Business Board for assurance and to the financial approver at each business case stage, with details of financial forecasts which include risk allowances. This will allow programme leads to consider the project in an affordable programme, influence future

		funding settlements and align timing of delivery to suit funding availability.
3	Lack of evidence to support case for change	The SOC produced an options longlist and used the flood model to evidence benefits for each. Since production of the SOC, internal flooding has been experienced at Clydach Terrace during Storm Bert highlighting the ongoing and significant risk to the properties and highway. The shortlist has been further investigated and appraised in this OBC Stage. Project economics and technical delivery were assessed in the Initial Assessment and SOC and have been refined in the OBC, in accordance with WG FCERM Business Case Guidance, to ensure the project is only progressed further if it remains viable. The economic assessment has been further refined at OBC stage to assess the financial viability of the scheme. The OBC seeks to clearly communicate modelling and economic findings, including sensitivities and present upper and lower limits where possible.
4	Residual Flood Risk	Residual flood risk has been assessed for exceedance events as part of the OBC. The assessment of residual hazard has indicated that there is a significant risk on the highway and to properties on Clydach Terrace and elsewhere in the study area associated with the BAU and WAW scenarios. The residual risk is similarly high in an exceedance event where the wall option is overtopped or outflanked. A RUA as part of the OBC has determined the potential freeboard required for the wall option. The RUA has highlighted the significant uncertainty associated with the hydraulic model outputs, which are heavily influenced by the hydrological analysis and the subsequent rainfall values input to the model.
5	Reputational damage if no project option is economically or technically viable - Project has become high profile locally with involvement of MS and	Explain WG FCERM Business Case Guidance and FRM Capital Funding System to key stakeholders. The project team has developed a communication strategy. The community and key stakeholders will be kept updated with project progress.

	there is a keen interest from the community.	NRW supporting Multi-Agency working with RCTCBC and WG.
6	Stakeholders do not support the short-listed options and agreements can't be reached to take them forward.	Shortlist findings of options will require further consultation to ensure that options are understood by affected parties and relevant stakeholders. Where required, compensation estimates are included in option estimates.
7	Flood risk could be originating from other sources such as surface water or sewer overload could undermine benefits from managing the fluvial risk.	Worked with the LLFA and the sewerage undertaker (Dŵr Cymru Welsh Water) to better understand the sources of flood risk and any potential options or plans to manage respective risks.
8	All required permissions and consents for the chosen option may not be obtained	Permissions and consents may need to be obtained in relation to the project. These could include, but are not limited to, a Flood Risk Activity Permit, Highways Approval and planning permissions amongst others.
9	Negative environmental impacts	Negative environmental impacts avoided where possible, informed by ecological and environmental field surveys and studies where necessary. Mitigation strategies or compensation packages would be developed for any potential unavoidable negative impacts of any recommended option. Opportunities for net improvements in the natural environment were screened via desk based assessment, any promising avenues that align with the project were further explored.
10	Public misconception (of flood risk or options to manage)	Detailed public engagement sessions at each stage of the project lifecycle have gathered valuable local information and recollection of flood events, provided information on community/property resilience, and informed on the process/progress of FRM scheme delivery/appraisal.

Key Stakeholders and Working with Others

Table 6 provides a summary of the key stakeholders for the project. It is likely that further engagement with these stakeholders will be required at future stages of project delivery.

Table 6: Summary of Key Stakeholders

Stakeholders
External:
WG – Senedd • Alex Davies-Jones, MP for Pontypridd • Vikki Howells MS for Cynon Valley • Heledd Fychan MS for SWC Interest: MP representing their constituents Opportunities: Stakeholder working group, comms lead with residents
Rhondda Cynon Taf County Council (RCTBC) Interest: LLFA, Highway Authority, Planning Authority and Emergency Planners Opportunities: Collaborate with Highways Department on options appraisal and funding
Residents of Clydach Terrace Interest: Residents at risk from flooding Opportunities: Community stakeholder group
National Flood Forum (NFF) Interest: Flood Action Group Opportunities: Community stakeholder group
Utilities (DCWW) Interest: Protection of assets (upstream Reservoir) Opportunities: Improve collaborative working
Internal:
David Letellier – Head of Operations South Wales Central
Tim England – Operations Manager (Flood & Water Management)
Victoria Schlottmann – Team Leader Environmental Assessment Team
Ross Akers – Flood Risk Strategic Planning and Investment Manager
Andy Robinson – Team Leader People & Places Team

Darren Walsh – Team Leader Asset Performance
Mark Davies – Team Leader Integrated Engineering
Christopher Rees – Team Leader Forest Operations
Rhianon Bevan – Team Leader Land Management
Evidence, Policy and Permitting
River Restoration – Freshwater Ecosystems and Fisheries Management

The Stakeholder Engagement Plan for this project is combined with the Communications Plan, and can be found stored on NRW's systems here. A copy can be made available on request.

Since October 2023 Welsh Government have funded the NFF to offer support to Clydach Terrace residents including establishing a Flood Action Group and a Flood Action Plan and facilitating partnership working between Risk Management Authorities and the community.

At NRW's request, NFF collated a compelling Community Narrative (appended in full) summarising some of the lived experience of residents. "The huge financial, practical and emotional strain of flooding… impacts every aspect of our lives, day after day."

The Narrative details the severe impact of flooding on residents highlighting significant financial strain, extensive property damage, and profound emotional and psychological tolls. Residents feel unsupported by authorities, face high insurance costs, inadequate temporary flood defences, and poor communication. Residents describe prolonged uncertainty and lack of effective solutions disrupting the community, leading to anxiety, depression, and some families moving away. The Narrative calls for immediate, empathetic support and transparent communication to address the residents' urgent needs and burdens.

Knowledge share

Lessons learnt from issues which impacted previous, similar projects, have been identified. The topic, cause and impact to the project is discussed in Table 7.

Table 7: Summary of Knowledge Share

Have you reached out to seek similar projects within NRW and understand lessons learned?	Yes
IF YES: Which similar projects have you identified and what lessons learnt are relevant you this project?	

Project	Topic	Cause	Impact
Pwllheli FRM Scheme	Misalignment of expectations and scope with FRA Team on the hydraulic and hydrological modelling submission.	Limited direct communication between the Arup's modelling team and NRW's FRA Team.	Delay to programme (circa 4 weeks). Increased costs associated with revisiting modelling work.
Pwllheli FRM Scheme	The hydrology element of the modelling was submitted and received at the time as the hydraulic model.	Lack of protocol i.e. confirm agreement of hydrology approach with NRW prior to progressing to hydraulic modelling.	Delay to programme. Duplication of works/effort to retrospectively address the issue.
Porthmadog FRM Project	Production of a template for contacting statutory undertakers about their flood risk.	Flood model update showing infrastructure at greater risk.	Improved communication with third parties to seek to influence action.
Wemyss	Email from Stakeholder outlining the need for a narrative document or information of what advice has been taken forward from previous stages of consultation. Consultees are unaware of what they previously said and if it has been absorbed into the project.	Poor communication following stakeholder engagement.	Confusion during next phase of consultation. Stakeholders were not sure how their advice had been incorporated or forgot what they had said.
Wemyss	Local stakeholders requesting site meeting to review options being consulted on. This became known on	Partially low-quality documentation. Partially lack of understanding by stakeholder.	Additional cost and time.

	Pandora where the information shared to stakeholders was not sufficient quality. Farmer is requesting we talk through the options on site so he understands. The technical note has gone through Comms review, to ensure it is clear.		
Llwynypia	Appraisal, Design, Construction of flood assets adjacent to utilities (DCWW).	Utilities asset immediately adjacent to NRW asset potential to impact project viability.	Abortive spend.
Ammanford FRMS	Flood Risk Modelling.	Alignment with fish passage project led to late modelling of options and potential detriment mitigation optioneering became critical path.	Additional time and cost.
Ammanford FRMS	Data.	Understanding of local services and sufficient time in programme to allow for diversions. Sufficient time risk allowance in programme for planning consent.	Programme saving.
Carlisle Flood Scheme	Purchase by Agreement.	FRM scheme could not be economically resolved. The solution was to purchase the impacted isolated properties.	Novel use of purchase powers for flood risk.

Aberdulais	Fluvial modelling data.	Additional work was required to scrutinise the hydraulic model so that it could best inform the economic analysis and option appraisal.	Increased time and cost to revisit work.
Llangefni	Base lines (Walk away and Business as usual) across all criteria (environmental, flood risk etc).	Clear 'walkway' and 'Business as Usual' baselines definitions were not agreed early in the process.	Difficulties understanding the implications of 'do something options' with respect to informing option appraisal.
Llangefni	Options cost analysis.	Lack of early contractor involvement (ECI) and/or cost consultancy.	Lack scrutiny regarding the practical buildability and construction costs of concept designs, resulting in misleading delivery estimates.
Llangefni	Capital Project early closure plan.	No plan in place for early capital project closure should no viable FRM option be found.	Very reactive closure plan increasing risk and stress, limited joined up messaging from wider NRW regarding what closure means and what the future looks like (ie it's not a hard walk away from FRM, its close this capital project – which could be revisited should new evidence/ technology/policy be available.

A high level review of UK projects has also been undertaken, to identify whether there are lessons to be learned from other FRM schemes. which have identified a high risk to life, but where there has been no economically or technically feasible solution. None offer a direct parallel.

Economic case

Critical Success Factors

The Critical Success Factors (CSFs) can be defined as attributes essential to the successful delivery of a project. The CSFs are used to assess the potential options that have been identified. For an option to be considered viable, it must have the potential to meet all of the CSFs. It cannot be considered viable if it can only meet some of the identified CSFs or can only partially meet a CSF. A summary of the identified CSFs is given in Table 8.

Table 8: Critical Success Factors

No.	Critical Success Factor (CSF)	Description of CSF
1	Strategic fit and business needs	An option that reduces present day and future flood risk to people and property in Clydach Terrace, Ynysybwl, to improve the quality of life to the local community. An option that aligns with WBO and SMNR objectives.
2	Potential value for money	An economically viable option to manage flood risk, with a BCR greater than one.
3	Supplier capacity and capability	The option must match the capacity and capabilities of potential suppliers.
4	Potential affordability	An affordable option for WG FRM funding within financial year constraints, taking into account estimated costs.
5	Potential achievability	A technically feasible option to manage flood risk, with consideration of site-specific constraints, noting the need for consenting and community / homeowner support, with a maintainable option.

Options Analysis – Long List

The following table summarises the Long List Options Framework used to identify options previously taken forward to Longlist stage at SOC. This table was populated subsequent to discussions with key stakeholders. According to the FCERM-BCG, the framework considers the creation of options as a series of choices to be made in sequence. The first set of questions namely “Where” and “What” assist the appraisal in identifying the potential scopes for a project which includes: the Walkaway option, the Business As Usual option, a minimum of two intermediate options, and a Do Maximum option. Options are ordered from least to most ambitious, in terms of outcomes. The framework then asks that appraisals identify and appraise the choices in relation to the “How”, “Who”, “When” and “Funding”. The Walkaway and Business as Usual options have been automatically carried forward for comparison with identified options.

Where an AEP, or Annual Exceedance Probability, is referred to this indicates an annual chance of a flood of that magnitude occurring. For example, a 1% AEP event means there is a 1 in 100 chance in any single year of this flood event happening.

Table 9: Longlist Options Framework

Project	Walkaway	Business as Usual	Intermediate Option 1	Intermediate Option 2	Intermediate Option 3	Do Maximum
1a.Service scope (spatial) – as outlined in strategic case	N/A	Assets currently in place	Property scale	Local scale (Clydach Terrace)	Community scale	Catchment scale
	Carried Forward	Carried Forward	Carried Forward	Carried Forward	Carried Forward	Preferred Way Forward
1b.Service scope (temporal) – as outlined in strategic case	N/A	Assets in place (existing SoP)	20% AEP SoP (2020-2039, 5% climate change allowance)	2% AEP SoP (2020-2039, 5% climate change allowance)	1% AEP SoP (2020-2039, 5% climate change allowance)	0.1% AEP SoP (2020-2039, 5% climate change allowance)
	Carried Forward	Carried Forward	Discounted	Carried Forward	Preferred Way Forward	Discounted

Project	Walkaway	Business as Usual	Intermediate Option 1	Intermediate Option 2	Intermediate Option 3	Do Maximum
2. Service Solution – in relation to the preferred scope	Current services: Cessation of maintenance activities	Core services: Continuation of current activities	Core + Desirable services: reduce fluvial flood risk and maintain solution.	Core + Desirable services: reduce fluvial flood risk and maintain solution, plus amenity and biodiversity enhancement.	No Intermediate Option 3 for Service Solution.	Core + Desirable + Optional services[6]: reduce fluvial flood risk and maintain solution, plus amenity and biodiversity enhancement, plus further local biodiversity enhancements and scour protection.
	Carried Forward	Carried Forward	Discounted	Carried Forward		Preferred Way Forward
3. Service Delivery – in relation to preferred scope and solution	N/A	Current arrangements: local Asset Management team	Local Framework: RMA project team plus local consultants and contractors	Wales framework: RMA project team plus Wales-wide consultants and contractors	No Intermediate Option 3 for Service Delivery.	UK framework: RMA project team plus open tender and Find a Tender Service (FTS)
	Carried Forward	Carried Forward	Carried Forward	Preferred Way Forward		Discounted
4.Implementation – in relation to	N/A	Continue current activities	<1 year	1-3 years	3-6 years	6+ years

[6] As included in the FCERM guidance Service Solution table P.68 flood-and-coastal-erosion-risk-management-fcerm-business-case-guidance_0.pdf (gov.wales)

Project	Walkaway	Business as Usual	Intermediate Option 1	Intermediate Option 2	Intermediate Option 3	Do Maximum
preferred scope, solution and method of service delivery	Carried Forward	Carried Forward	Discounted	Carried Forward	Preferred Way Forward	Discounted
5.Funding – in relation to preferred scope, solution, method of service delivery and implementation	N/A	Revenue funding (public)	Capital funding (public)	Capital funding (public) via innovative funding mechanism e.g. FCERMP	No Intermediate Option 3 for Funding.	Capital funding (public) plus external contributions
	Carried Forward	Carried Forward	Carried Forward	Preferred Way Forward		Discounted

A summary of the decisions made to refine the longlist definition is provided below.

Service scope (spatial): The Preferred Way Forward would be to provide a solution at the catchment scale. However, other options at the property, local and community scale will be considered. These have been carried forward.

Service scope (temporal): The 20% AEP SoP has been discounted as it is not considered to provide a substantial increase in flood protection. A SoP of the 0.1% AEP event has been discounted as it is considered that it would be difficult or technically infeasible to provide protection measures in an event of this magnitude. The 2% AEP and 1% AEP SoP have been carried forward as providing this SoP as part of the project is considered feasible and would provide an improved SoP over the existing situation.

Service Solution: The Preferred Way Forward would provide the Core + Desirable + Optional services set out in the scope. The Core + Desirable services plus amenity and biodiversity enhancement has been carried forward as an attainable solution. The option with Core + Desirable services comprising reduction in flood risk and maintenance of the solution has been discounted as it does not provide a significant wider benefit.

Service Delivery: The Wales framework has been identified as the Preferred Way Forward, with the Local Framework carried forward[7]. This provides the most options in terms of service delivery when considering the potential project complexity and programme requirements.

Implementation: An implementation timescale of <1 year has been discounted as it is not considered realistic. Implementation periods of 1-3 years or 3-6 years have been carried forward. The 3-6 years proposed timeframe is considered most realistic.

Funding: Capital Funding has been carried forward as an established method of financing FCERM projects in Wales. Capital funding plus external contributions has been discounted as it is not considered to be an option in the study area. Capital funding via an innovative funding mechanism, such as FCERMP, has been chosen as the Preferred Option.

As a result of the input received from key decision makers and stakeholders, the Options Framework filter has now set the parameters for options to be carried forward for the development of a Long List of FCERM Measures.

Long List Options Appraisal

During the SOC an initial list of potential FRM options was developed based on a series of discussions between project stakeholders, and project team. For continuity and ease of reading, the following series of tables from the SOC have been included, to summarise each longlist option as considered during the SOC stage. Options were qualitatively assessed based on estimated cost, advantages and disadvantages and against CSFs. This determined whether options should be shortlisted for further appraisal. Walkaway (WAW) and BAU options have also been included as a baseline. As part of the OBC appraisal, the

[7] FCERM guidance, SWOT Temporal Scale table p.67 flood-and-coastal-erosion-risk-management-fcerm-business-case-guidance_0.pdf (gov.wales)

longlisted options have been reviewed so they reflect the latest available information and assessments that have been undertaken.

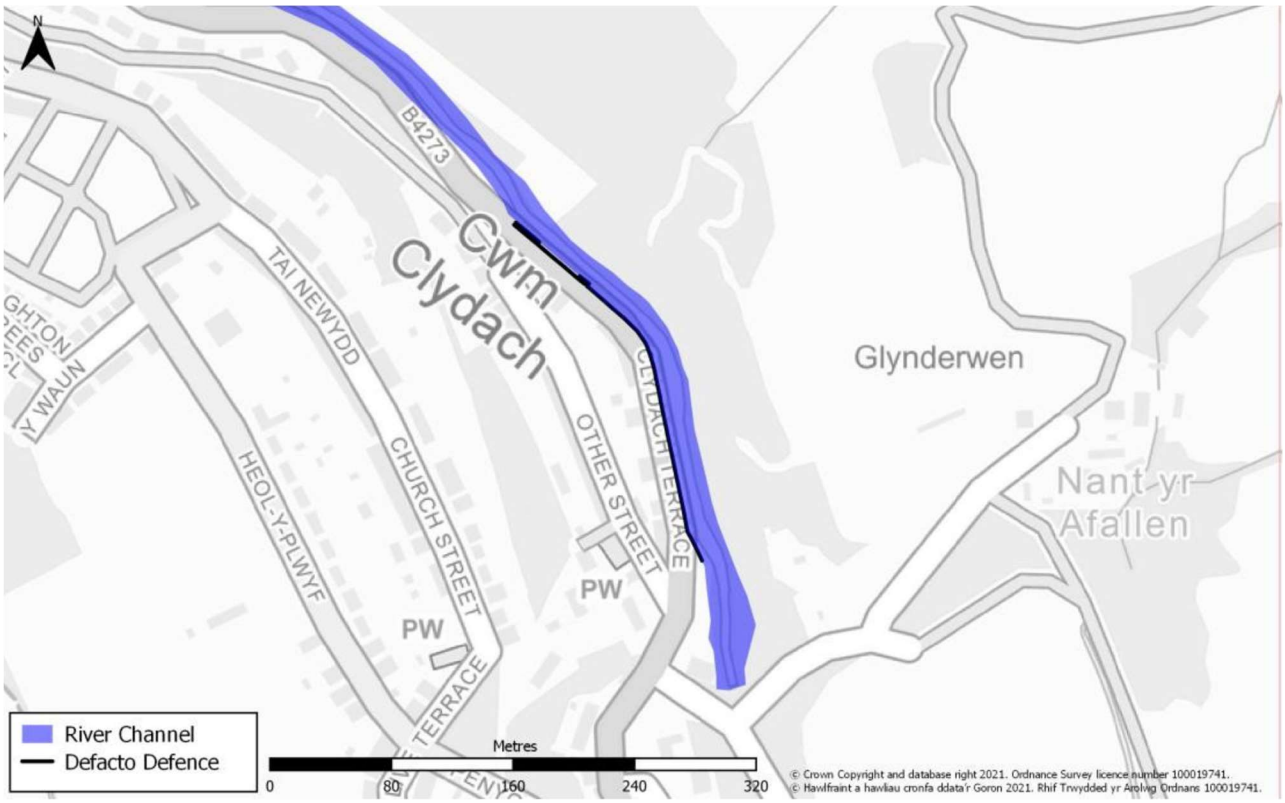
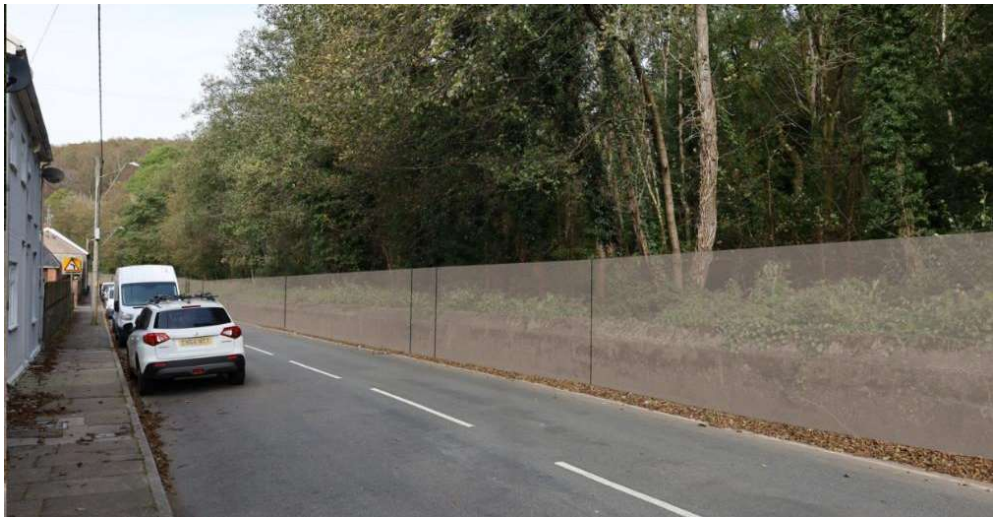


Figure 12: Plan of existing highway wall on Clydach Terrace

Figure 13: Highway wall on Clydach Terrace (looking downstream)

Option 1	
Description	**Raise and upgrade existing highway wall.** Replacing and raising the existing highway wall at Clydach Terrace so it performs as a formal FRM asset, offering an improved SoP.  *Figure 14: Raising and upgrading existing wall (photo montage of 1 %AEP height wall outside No.4/5 Clydach Terrace)* The wall height shown in the image above is indicative only, as it represents the approximate wall height to achieve the required SoP without additional freeboard. The outcome of the Residual Uncertainty Analysis (RUA) has indicated that additional freeboard would be required to provide confidence in the SoP offered by the wall and therefore the wall is likely to be significantly higher than shown.
Costs	Anticipated high cost relative to WAW and BAU options.
Advantages	• Model indicates that raising the height of the wall reduces the risk of fluvial flooding to properties and people on Clydach Terrace. • Social and wellbeing value in terms of the residents knowing their homes are at a lower risk of fluvial flooding. • Potential reduction in other maintenance costs, including shoal removal as wall improves on the existing SoP, design can improve access, or might not be impacted by shoal being managed by natural processes. Reduction in post flood event costs including clean up as wall reduces risk of fluvial flooding to properties.
Disadvantages	• The increased wall height (compared to existing) would become a greater visual barrier to the river. • Road may need to become single carriageway and there may be encroachment towards the riverbank resulting in habitat loss.

Option 1	
	• Potential for loss of habitat through requirement for continuing the ongoing channel maintenance which could result in a reduction of quality of aquatic habitat for fish and invertebrates. • Operational maintenance required by NRW, if the wall is adopted by NRW. The wall is currently owned and maintained by RCTCBC. • Potential for habitat disturbance/loss should vegetation clearance be required. • There is little space along B4273 road and therefore this may need to be closed during construction. Alternative route through Ynysybwl is not as suitable as main route through the village. • Potential disproportionate impact to people with reduced mobility, who may be more severely impacted by road closures or reduced vehicular access to properties on Clydach Terrace. • Medium carbon cost associated with construction of the new wall; this may be minimised by selection of materials and construction methods. • A secondary flooding mechanism is observed where surface water flow ponds behind the wall. This residual risk reduces the effective SoP of the option. • Flood and life risks during exceedance events remain.
Assessment against Critical Success Factors	This option satisfies the strategic fit and business needs, as the hydraulic modelling has indicated that this option can provide a reduction to fluvial flood risk at Clydach Terrace including highway users. The improved SoP offered by the option is likely to improve the quality of life of the residents. However, some residents have expressed concerns that the option would disconnect them from the river, impacting light levels, reduce parking availability for vehicles, and negatively impact the value of their property. The option was identified at SOC as potentially economically viable and provide value for money. The option matches the capacity and capability of potential suppliers. The option remains technically feasible, though consideration must be given to site-specific constraints such as utilities infrastructure. The option is maintainable. Potential to meet CSFs.
Conclusion	Shortlisted.

Option 2	
Description	**Natural Flood Management (NFM)** Implement NFM in upper catchment. There are opportunities upstream, including using WGs' Woodland Estate at Llanwonno Forestry.
Costs	Low cost for NFM option alone
Advantages	• Incorporating NFM measures would somewhat reduce flows into the Nant Clydach, along with potential benefits elsewhere in terms of ecology and the environment. • NFM could result in an increase in riparian habitat complexity, reduction in sediment, shoal, woody debris, transportation downstream and creation of microhabitats beneficial for a range of aquatic/semi-aquatic species. • NFM option would support Part 1 of the Environment (Wales) Act; 'sustainable management of natural resources', which puts priority on nature based solutions. • Less new embodied carbon spend vs other options.
Disadvantages	• NFM alone would not reduce flood risk to desired levels. • Agreement with owners of upstream land and purchase may be required, which can be difficult and time consuming to achieve
Assessment against Critical Success Factors	The preliminary assessment of potential flood flow reduction at Initial Assessment stage used the Flood Risk Assessment Wales Economic Toolset (FRAW ETS) identified that maximum flow reduction achievable by implementing widespread NFM measures in the South East valleys basin of 26.9%. This is comparative to the climate change uplift values for the Severn basin. The assessment concluded that potential reductions in peak flows provided by NFM are likely to be nullified by increase in flood flows as a result of climate change. A more detailed NFM assessment as part of this OBC used the NatureInsight® tool, which identifies land areas which are suitable for various NFM interventions. Opportunity mapping explored four scenarios at a high-level and showed the catchment has good suitability for a range of NFM interventions. The NFM feasibility assessment identified that there is potential to deliver widescale NFM within the Ynysybwl catchment and that this could help reduce peak flows during the 5% AEP event by between 5.7% and 9.8%. These peak flow reductions can help increase flood risk resilience in the catchment, whilst also providing wider benefits to the environment and local community. This assumes that all interventions with a 'good' score in the NI tool assessment are implemented. Wider benefits have been quantified at a high-level. The equivalent ranges of net

Option 2	
	carbon sequestered and net habitat units added are 324-1,425 TCO2r/yr and 567 – 1,586 units, respectively. Based on these assessments, the NFM option alone would not significantly reduce fluvial flood risk to people and property on Clydach Terrace. However, the option would still provide some flood risk resilience benefit to residents and highway users. The option aligns with SMNR principles. The NFM option is likely to be affordable, and value for money is enhanced when considering the wider ecological and environmental benefits. However, the OBC assessment indicated that the reduction in flow achievable with NFM is unlikely to make a significant difference to the flooding experienced during larger events, and the reduction in smaller events is relatively small when compared to the future impact of climate change. The option matches the capacity and capability of potential suppliers. The option is technically feasible. It is considered that the NFM option is unlikely to meet the CSFs. However, the NFM option has the potential to partially meet all CSFs and therefore could be considered in combination with other option/s.
Conclusion	Not a standalone option because the impact on flood risk is considered to be low. Potential for NFM to be incorporated in combination with preferred option. Further consideration has been given to this option at OBC. The study concluded that the overall reduction in flows provided by NFM would not significantly reduce the flood risk to Clydach Terrace as a standalone measure.

Option 3	
Description	**Purchase by agreement** Properties would be purchased by agreement, and residents moved away from the flood risk area. This would assume that NRW could exercise its compulsory purchase powers (CPO) or at least work within the same principle if agreements with homeowners were reached outside of the CPO process, which would mean that any acquisition would be made in line with the relevant legislation and compensation code. The purchase of property by agreement for the management of flood risk is a novel approach and, as such, there is currently no policy or process in place. Accordingly, NRW is unable to provide any further detail on process.

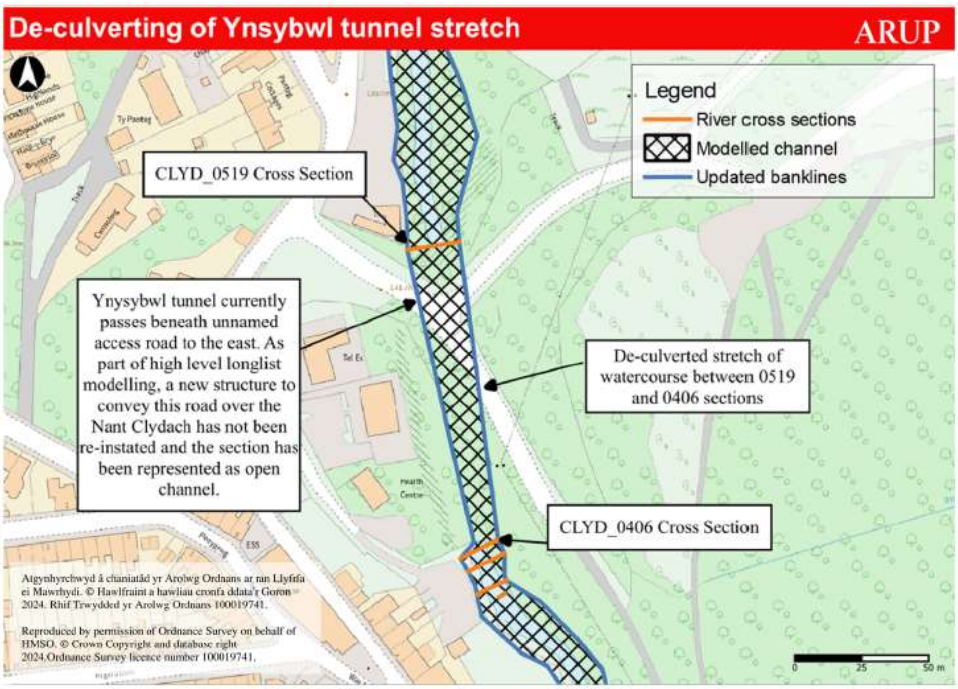
Option 3	
Cost	High cost - **Includes high-level valuation of the properties to be purchased and the cost of demolition and remediation.*
Advantages	• No present day or future flood damage costs to properties at Clydach Terrace at high risk of deep, rapid, internal, fluvial flooding. Associated reduction in maintenance costs and post-event maintenance activities including clean-up somewhat reduced. • There is a potential positive social impact to those residents who have relocated, as they do not have to live within a flood risk area. However, relocation may also have negative social impacts as recognised below. • In addition to the associated savings, potential cessation or reduction of channel maintenance would have the potential to allow the river channel to return to a more natural state. This provides potential benefits from a WFD and wider environmental point of view in terms of improving habitat complexity, with associated benefits to important riparian habitat for a range of aquatic and semi-aquatic species. • Depending on the use of this land around Clydach Terrace after demolition of the properties, there may be wider benefits including increased amenity or recreational space and ecological/environmental benefits.
Disadvantages	• Option would involve demolition of properties at high risk. With this, there is little space along B4273 road and would potentially require it to be closed for a period of time. Alternative route through Ynysybwl is potentially not suitable as main route through the village. Potential disproportionate impact to people with reduced mobility, who may be more severely impacted by road closures or reduced vehicular access to properties in Ynysybwl. • Novel 'set back' adaptation approach with wider interest/communications anticipated. • No policy or procedure in place to guide this option. This would take time to develop to ensure an auditable process is agreed and followed. • The residents of Clydach Terrace are a close knit and supportive community, with many residents having long-standing ties to the area. Relocation may weaken or break these ties and subsequently have a detrimental impact health and well-being. There may be a disproportionate impact on elderly people or vulnerable people who may have lived in the area for a long time. The solution broadly relies on affected properties reaching consensus. • Ynysybwl is an old mining town and the properties along Clydach Terrace have cultural value as part of the industrial heritage of Ynysybwl, which would be lost if these properties

Option 3	
	were demolished. This could be mitigated by creating an educational space or signposting within the area created by the demolition of the properties. • May disproportionately impact those people with additional needs in terms of housing, as they may be less able to find comparable housing elsewhere. Children who are required to move schools would be disproportionately impacted as a result of disruption to schooling and social groups. • Medium to high carbon spend depending on the method of reinstating the area. • Legal consenting would be required for this option to go ahead.
Assessment against Critical Success Factors	Has potential to meet CSFs, but merits further investigation into its feasibility. The option would reduce present day and future flood risk to people in Ynysybwl by removing them from an area with high flood risk. However highway users would continue to be at risk or increased risk of flooding. • The option has the potential to offer value for money. The option is potentially affordable. This option does not have an agreed policy or procedure in place that confirms how FRM can be utilised. The option meets supplier capacity and capability. The option is technically feasible. The option is achievable based on the site constraints.
Conclusion	Shortlisted.

Option 4	
Description	**Flood Warning System (FWS)** FWS introduced, including required gauging equipment.
Cost	Low cost for Flood Warning System installation alone.
Advantages	• Provides the residents some warning to place valuables in a safe place and evacuate the properties. Improves resident's feeling of safety as they can prepare for a potential flood event. • Minimal carbon spend.

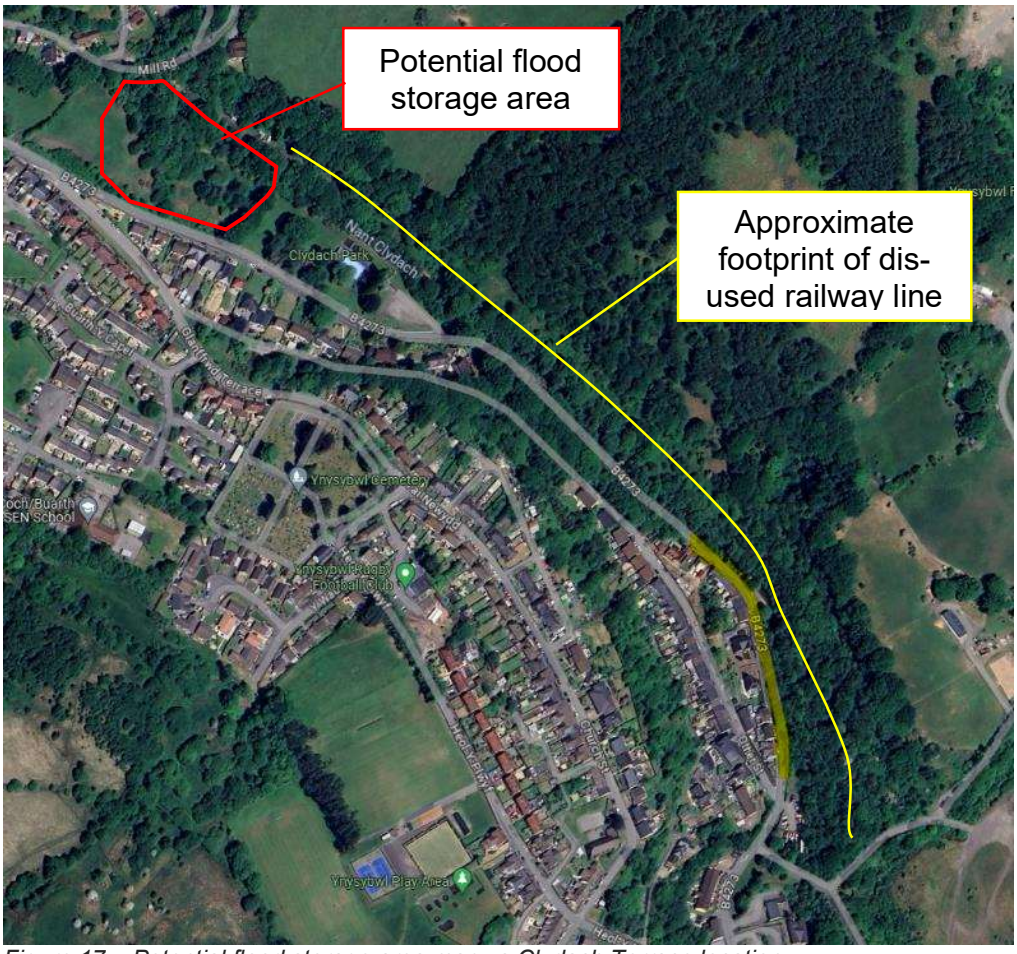
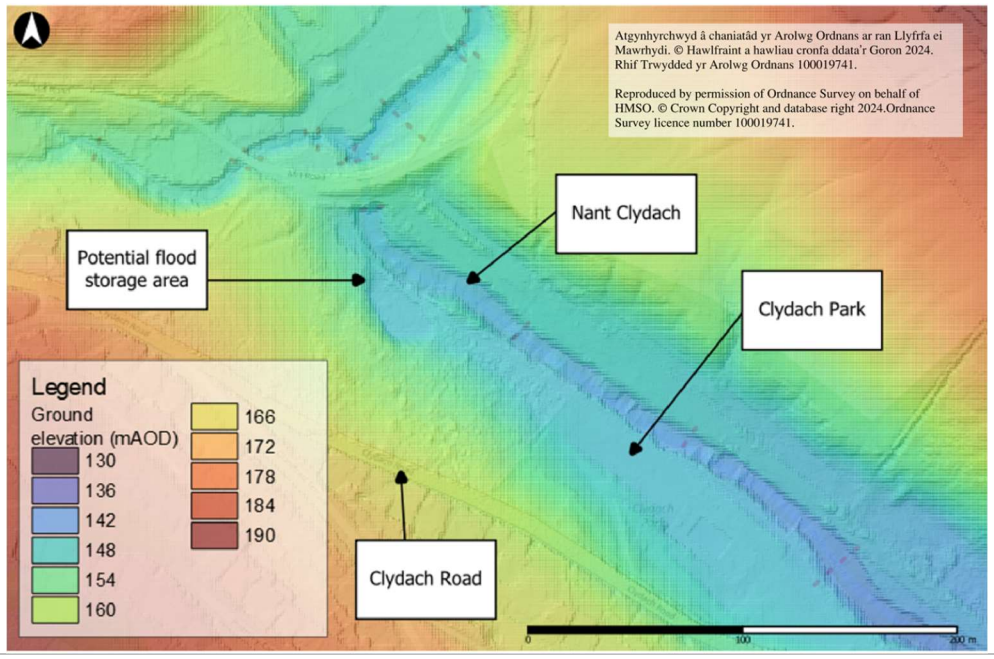
Option 4	
	• Can be used in combination with other measures to improve overall risk management. May be technically easier to provide in combination with other measures.
Disadvantages	• Requires information from river and rain gauges along with soil moisture capacity to provide accurate warning system. • Costs associated with installing and maintaining gauges that provide data for the warning system. • Likely temporary habitat disruption or impacts to fish arising during the installation of gauges. • The catchment is steep and narrow, with a fast response to rainfall. In this sort of catchment, it can be difficult to install an effective flood warning system that provides enough time for residents to respond in advance of a flood event. • There may be false warnings that may reduce resident response rates to a warning. • Option may be less effective for those with reduced mobility or additional needs as they may be less able to respond to the flood warning system. Elderly people may have difficulty in accessing or responding to a digital warning system.
Assessment against Critical Success Factors	This option does not meet the Strategic fit and Business needs as it does not reduce the risk, through measurable change in SoP, both now and in the future. It has the potential to reduce the consequences of a flood event by giving residents advance warning. Appraisal of this option as part of the Initial Assessment stage flagged that the time to peak in the catchment can be as little as 3 hours. As such, it would be difficult to provide significant warning of an impending flood event. The Initial Assessment also flagged that the antecedent conditions heavily influence the scale of the flood event experienced at Ynysybwl during periods of increased rainfall. To be effective, the FWS would need to take this into account. The flood warning system alone is likely to provide value for money and would be affordable. There would be ongoing maintenance and operational costs in terms of maintaining the gauge and FWS and gathering the required data. The option is likely to meet both supplier capacity and capability. The option is likely to be achievable. Further work to identify the amount of flood warning and the reliability of the warning in the catchment would be required.
Conclusion	Shortlisted, but not assessed further at SOC stage due to RAD tool methodology limitations (the RAD tool does not allow for inclusion of the benefits of a flood warning system) and the Initial Assessment considered that Flood Warning alone would not offer a viable option.

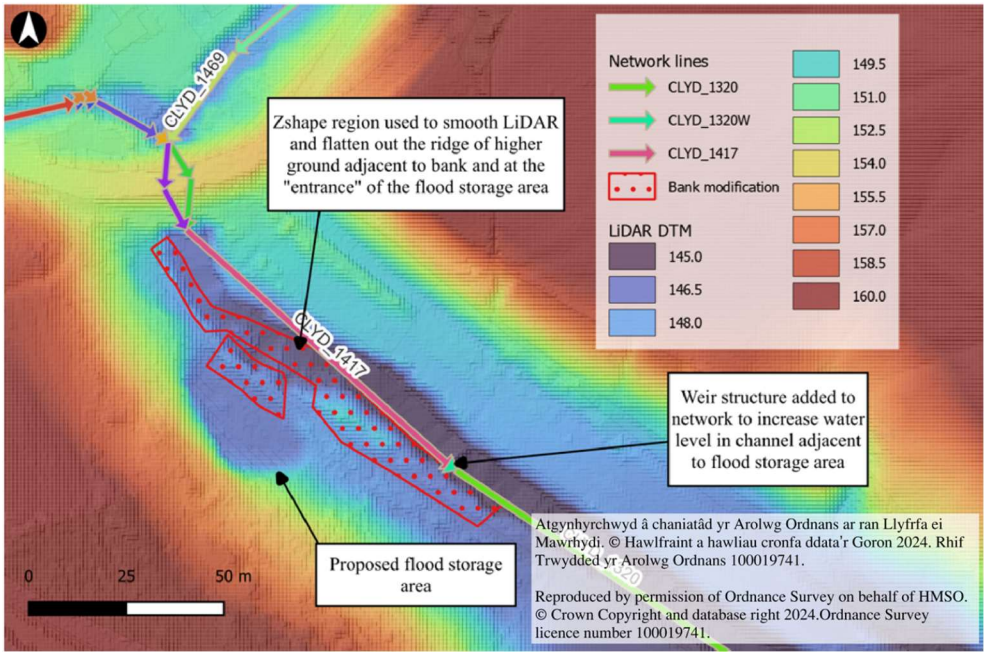
Option 4	
	At OBC it is concluded this option would not be likely to be achievable, as it is not possible to provide a flood warning service for the community that meets NRW SLA. A novel or simplistic option would be required instead, with concerns regarding the effectiveness of these due to the rapid response time of the catchment and the high likelihood of 'false alarms'. Therefore, this option is discounted.

Option 5	
Description	**Remove/improve downstream culvert** Existing highway wall would be upgraded to perform as FRM asset at its current height, and culvert would be removed or improved to not be a hydraulic restriction for events up to the design SoP.  *Figure 15: Culvert location plan*

Option 5	
	 *Figure 16: Culvert (photo taken from the South end, looking upstream)*
Cost	Very high cost
Advantages	• Reduces flood risk in the 3.33% AEP scenario for all properties. • Potential for reduction in maintenance costs in terms of debris removal or reactive maintenance of the structure. • Daylighting of the watercourse in this location could provide marginal social and wellbeing benefits in terms of increased awareness and visibility of the watercourse. • Improved aquatic and riparian habitat through the reach, potential for increased re-naturalisation of channel. This aligns with the aims and objectives of the WFD. • Potential to re-establish a more natural channel profile. • Improvement in potential for fish passage and removal of barrier to otter passage up and downstream.
Disadvantages	• For flood events that exceed 3.33% AEP event, removal of culvert has minor impact on flood extents and depths. • Due to threshold heights of the buildings on Clydach Terrace and the flood depths observed, it is likely that, even with the culvert removed, substantial internal flooding would still occur. • De-culverting would be complex and costly as it would involve day-lighting the culvert/rock tunnel. • The culvert currently carries an over bridge, full removal would require a replacement bridge to be constructed.

Option 5	
	• The conveyance capacity of the bridge would need to be increased relative to the existing structure otherwise the de-culverting would offer little flood risk benefit. • May increase flow velocity as culvert is removed. Therefore, a geomorphological assessment would be required to assess whether there would be any longer term impacts in terms of channel morphology. Although this could also be a potential advantage if the evidence shows that sediment transport is being restricted by the culvert. • Downstream impacts to be assessed, with risk of impact on third parties. • Would require works adjacent and in the watercourse. High flows may prohibit this and impose programme delays. • Traffic management would be required along the unnamed access road, and a diversion may be required for residents to access their properties. This may be disruptive as the access to the properties from the north is via dirt tracks that may not be suitable for all vehicles. This may disproportionately impact those with decreased mobility due to the reduced vehicular access to Ynysybwl and properties to the north. • Likely temporary habitat disruption or impacts to fish arising during the construction phase. • Potential for high-level of pollution during de-culverting and upgrading of highway wall. • There would be a high carbon cost associated with the removal of the culvert and also the construction of the new bridge.
Assessment against Critical Success Factors	This option provides some flood risk reduction benefit in more frequent events but does not provide a reduction in larger order events, where the impact of the flood event is much greater. Hydraulic modelling has shown that the option is unlikely to prevent internal property flooding in flood events exceeding the 3.33% AEP event. As such, it is not considered to meet the Strategic fit and Business needs. The option is likely to be expensive and, as the reduction in flood risk is not substantial, is unlikely to provide value for money. The option is potentially achievable and meets the capacity and capability of the supply chain. The option is considered unable to meet the CSFs.
Conclusion	Discounted option.

Option 6	
Description	**Offline Flood Storage/Reconnecting the flood plain** Existing flood plain utilised as storage.  *Figure 17 – Potential flood storage area map vs Clydach Terrace location* 

Option 6	
	Figure 18: Ground Elevations indicating some potential Flood Storage locations  *Figure 19: Schematisation of some potential flood storage locations*
Cost	Anticipated medium/high cost
Advantages	• There may be some opportunity to combine the excavation and expansion of the flood storage areas with provision of recreational or amenity spaces. • Potential for NFM storage options, such as naturalised offline ponds, which could provide a host of ecological benefits. Floodplain management strategies have potential to be of value to local wildlife and habitats. • Storage focused NFM measures are likely to be less carbon intensive compared to engineered options however a suitable location would need to be determined.
Disadvantages	• Model shows that flood storage area to north-west of Clydach Park fills during small flood events but does not have appreciable storage volume in comparison to capacity of watercourse and flows observed. • Significant amount of excavation would be required to achieve desirable storage volume to reduce flood risk. This material may have contamination from historic industry and would need to be transferred and disposed of, incurring additional costs. • Additional structures would be needed to control flow from flood storage back to the river. • Landownership unknown. Potential to increase project costs. • Potential visual and landscape impacts associated with the excavated areas.

Option 6	
	• Potential habitat loss and disturbance should vegetation clearance be required. • There would be a high carbon cost associated with the removal of large volumes of material.
Assessment against Critical Success Factors	Assessment at Initial Assessment stage estimated that substantial excavation would be required on the left bank (22,400m^3) of the Nant Clydach to lower ground levels enough to allow water to enter the area that is currently behind the disused railway line. Hydraulic modelling assessed the potential of using the area to the north of Clydach Park as flood storage at SOC stage. The exercise indicated that this area is likely to fill during lower order flood events and therefore does not provide substantial storage during larger flood events, where there are greater volumes of floodwater. The option does not meet the Strategic fit and Business need as it does not reduce the flood risk in the present day or in the future. Although there may be wellbeing benefits associated with using the flood storage area as an amenity or recreational space, it would not improve wellbeing in terms of reduced flood risk. The substantial amount of excavation required would make this option expensive, and therefore likely to be unaffordable. Similarly, there would be a large amount of excavated material that would need to be treated and moved elsewhere. Due to the limited flood risk benefit, this option would be unlikely to provide value for money. The option is likely to meet supplier capacity and capability. The option does not meet all of the CSFs.
Conclusion	Discounted option

Option 7	
Description	**Property Flood Resilience** Installation of passive PFR measures at the properties on Clydach Terrace.
Cost	Low cost in comparison to other options.

Option 7	
Advantages	• Magnitude of property flood damages reduced. This option may be particularly effective in managing residual flood risk from pluvial flooding. • Low carbon cost in comparison to other options.
Disadvantages	• Properties and people remain at risk of flooding. • Potential for access/egress issues of residents remain in properties during flood events • PFR ineffective in locations prone to deep flood waters (>0.6m). • The effectiveness of this option could be improved with the installation of an effective Flood Warning System for Ynysybwl providing time for residents to evacuated properties. However, it is not possible to provide a service that meets NRW SLA; this therefore limits the potential effectiveness of this option in the community. • Installation of PFR as a temporary measure, claims flood risk benefits (through avoided damages) reducing the potential benefits that can be provided and claimed through more wholesale options, therefore impacting their affordability.
Assessment against Critical Success Factors	The PFR option is unlikely to be effective against flooding in a large fluvial event, as depths are likely to exceed the limit of PFR viability (>0.6m depths). However, PFR is suitable for use to address residual flood risk, for example from pluvial flooding. However highway users would continue to be at risk of flooding. The PFR option alone is low cost, affordable, and meets supplier capacity and capability. It is unlikely to provide value for money, as PFR is ineffective against predicted fluvial flood depths. The PFR option is achievable. The option has the potential to partially meet the CSFs.
Conclusion	Not a standalone option but can be incorporated with other options. Note demountable flood gates have been actively offered to all residents at each Multi-Agency meeting.

Option 8	
Description	**Debris Management** This option would incorporate multiple methods of reducing blockage risk by managing debris upstream of Clydach Terrace, particularly in

Option 8	
	the upper catchment. This could be management of bank vegetation or providing screens and mechanical equipment.
Cost	Medium cost
Advantages	• Reduces risk of blockages along the river which subsequently decreases the chance of flooding. • May have potential to reduce maintenance costs. • Low to medium carbon cost depending on the approach taken and volumes of debris to be moved.
Disadvantages	• Does not improve SoP at Clydach Terrace. • Would have maintenance costs as any debris that is caught on screens would need to be removed. • Potential for loss of vegetation and habitat loss associated with installation of debris catchers or screens. • Potential barriers to otter and fish if not considered within design chosen. • If tree thinning is undertaken there may be habitat loss. • Removal of deadwood reduces habitat complexity. • Depending on solution, may impact the “natural” look of the channel.
Assessment against Critical Success Factors	The flood risk impact of this option cannot be quantified. Measures could be installed to reduce the amount of debris that could enter the channel, but it would not be possible to eliminate debris entering the watercourse from all sources, particularly during high flows. Therefore, the exact impact of this measure in terms of flood risk could not be guaranteed. Would potentially reduce maintenance costs at Clydach Terrace but would increase costs elsewhere as active maintenance in the upper catchment or regular clearing of new screens would be required. In the long term, the option may not provide value for money due to ongoing maintenance. This option is likely to meet supplier capacity and capability and initial affordability. The option is likely to be achievable.
Conclusion	This option is not considered as a standalone option as it does not have the potential to fully meet all of the CSFs. The impact in terms of flood risk is difficult to quantify. Not a standalone option but could be incorporated with other options.

Option 9	
Description	**Reduce bed level of watercourse and culvert section** Lower bed level in the river and culvert section to increase conveyance capacity of river.
Cost	High cost
Advantages	• River has additional capacity that may reduce flood risk to some extent.
Disadvantages	• Anticipated that the bed level would need to be significantly lowered to accommodate increased flow volume for extreme flood events. Further assessment necessary to determine by how much the bed would be lowered. • Loss of habitat. The loss of natural features along the channel and loss of riparian habitat complexity. Potential long term fish passage barrier, and barrier to otter, this would require ongoing mitigation. • Ongoing maintenance necessary to maintain riverbed at certain level, maintenance would prevent re-naturalisation of the watercourse. • Repeated pollution impacts from dredging also to be considered as this would result in a highly modified channel and consequent habitat degradation and reduction in biodiversity. • Medium carbon cost associated with the initial removal of material and ongoing management.
Assessment against Critical Success Factors	Unlikely to meet Strategic Fit and Business Needs as this option is unlikely to provide a significant reduction in present and future flood risk at Clydach Terrace. There may be some reduction, however further work would be needed to quantify the level of bed lowering that would be required to provide a flood risk benefit. Achievability is likely to be low due to constraints such as the small working area and proximity to the highway and wall. Bedrock is potentially present in channel which would make lowering bed level more difficult. This option may not match the capacity and capability of potential suppliers due to the site constraints. Due to difficulty in achieving the option, it is unlikely that it would be affordable or provide value for money.
Conclusion	Low potential to meet all CSFs due to lack of flood risk benefit. This option may not be achievable due to the presence of bedrock in the channel.

Option 9	
	Discounted option.

Option 10	
Description	**Widening of river channel** Widening of river channel to increase capacity of river.
Cost	High cost
Advantages	• River has additional capacity that may reduce flood risk to some extent. • Some potential to re-meander sections of the river which could be beneficial in terms of habitat provision in the long term.
Disadvantages	• River would need to be significantly widened to accommodate flooding volume of more extreme events. This would more than likely not be possible due site constraints (highway and properties on one side & steep topography on the other with potentially contaminated legacy spoil). • Widening the river would require large excavation and movement of material which would cause significant habitat loss. • Known invasive non-native plant species such as Japanese knotweed in the area. Soil and excavated material would have to be disposed of correctly. • River would flow closer to the highway wall, with a higher likelihood of erosion impacting the structural integrity of the wall. • Loss of habitat, including potential loss of ancient woodland (Ref PEA p44, Statutory and non-statutory designated sites and ancient woodland). The loss of natural features along the channel. As such, permanent impacts expected on aquatic/semi-aquatic species that rely on these habitats. Loss of habitat would require mitigation and compensation under planning policy Wales to demonstrate net benefit for biodiversity. • High carbon cost associated with moving large volumes of material.
Assessment against Critical Success Factors	It is considered unlikely that this option alone could meet the strategic fit and business need, as based on the high flow volumes in the river, significant excavation would be required to provide substantial additional capacity. Unlikely that this option alone could provide significant flood risk reduction both now and in future.

Option 10	
	Potential for high ecological impact, does not align with SMNR principles. Limited potential for achievability based on proximity of the wall and highway. Limited potential for affordability or value for money based on the difficulty of achieving this project option. Similarly, there is limited potential for supplier capacity and capability due to the constraints in implementing this option.
Conclusion	Discounted option.

Option 11	
Description	**Raising property levels**
Cost	High cost due to technical difficulty/infeasibility
Advantages	• Living space and all valuables would be above the flood level. The impact of a flood event would be reduced.
Disadvantages	• Residents and properties still within flood risk area, with access and egress issues. Unlikely to increase quality of life of residents. • Likely to disproportionately impact people with reduced mobility who may be less able to use upper floors as their living space. Housing may need adaptation to make upper floors more suitable for living and make access easier. • Would need to raise the level of each property significantly to be above the flood level. • Suitability and practicality unlikely given terraced property construction.
Assessment against Critical Success Factors	This option does not meet the strategic fit and business need as the fluvial flood risk is not reduced either in the present day or future. This option reduces the potential consequences of a flood event but does not address the risk. The quality of life of the residents of Clydach Terrace is unlikely to increase substantially as they remain within an area of high flood risk with access/egress prevented during events. This option is not practically achievable, due to the characteristics of the existing properties (mainly terraced houses). It would be difficult or

Option 11	
	impossible to either raise the properties above the flood level or extend the properties to include more storeys. The option is unlikely to meet supplier capacity and capability due to the technical difficulty of this option. The option is unlikely to be affordable or provide value for money due to the complexity of carrying out this option. This option does not meet the CSFs.
Conclusion	Discounted option.

WAW	
Description	**Walkaway** Involves cessation of all current activities including shoal removal, tree management, inspection, maintenance, repair, and review of existing flood risk. It is considered likely that the highway wall condition would deteriorate once maintenance ceases, increasing risk of breach.
Cost	No cost
Advantages	• Reduced ongoing maintenance cost. • Cessation of maintenance would have the potential to allow the river channel to return to a more natural state. If vegetation clearance and de-shoaling were not undertaken, there would be potential benefits in terms of improving habitat complexity, with associated benefits to important riparian habitat for a range of aquatic and semi-aquatic species. • This option has the lowest carbon cost.
Disadvantages	• People and properties would be at increasing risk of flooding due to climate change and lack of maintenance. Failure of the wall may be a hazardous breach with no warning. There may be disproportionate impacts of flooding on those with mobility issues, the elderly, or young children, as they would be less physically able to move away from flood waters or may be vulnerable to other health impacts arising from flooding. • Increase in property damage as flood frequency and impact worsens in future. • Residents would continue having to live within the flood risk zone, with associated impacts on wellbeing.

WAW	
Assessment against Critical Success Factors	Whilst it would save ongoing costs, the Walkaway option increases the present and future fluvial flood hazard to the properties on Clydach Terrace and highway users. There are limited wellbeing or community benefits and therefore unlikely to provide improvements in terms of quality of life of Ynysybwl residents. This option involves no action. This option does not meet all of the CSFs.
Conclusion	Not recommended but shortlisted for business case purposes as an additional economic baseline for comparison with potential options.

BAU	
Description	**Business as Usual** Continuation of existing Nant Clydach channel maintenance regime and formalising maintenance of the standard of service (SoS) of the existing highway wall at Clydach Terrace for the purposes of FRM. The construction and long-term performance of the highway asset as an appropriate FRM asset is not known.
Cost	The costs associated with maintenance of this structure have been included for the purposes of economic appraisal and option comparison under the SOC and OBC. The wall maintenance cost was included for comparison between BAU costs (not only NRW) to the proposed options. Ongoing maintenance costs are likely to significantly increase in future as the wall condition deteriorates and the chance of overtopping increases.
Advantages	• Existing highway wall SoS is maintained. • Current environmental impact is maintained. • Low carbon cost.
Disadvantages	• Fluvial flood risk to properties on Clydach Terrace would increase in future. It is likely that with the impacts of climate change flood events would become more frequent and more extreme. • Maintenance cost would continue or increase. Risk that the condition of the wall deteriorates which would require more frequent maintenance or repair to maintain SoS. • Does not contribute to well-being objectives.

BAU	
	• Ongoing channel maintenance, including shoal removal, could result in potential reduction in quality of aquatic habitat for fish and invertebrates. • There may be disproportionate impacts of flooding on those with mobility issues, the elderly, or young children, as they would be less physically able to move away from flood waters or may be vulnerable to other health impacts arising from flooding.
Assessment against Critical Success Factors	This option is more affordable in comparison to other options, as it avoids significant capital construction costs. It is likely that costs would increase in future as the condition of the highway wall deteriorates. This option does not fit the strategic fit and business needs as there is no reduction in flood risk in the present day or in future to properties or highway users. This option is achievable and further meets the capacity and capability of the supply chain. Limited wellbeing or community benefits and therefore no improvements in terms of quality of life of Ynysybwl residents. This option does not meet all of the CSFs.
Conclusion	Not recommended but shortlisted for business case purposes as the main economic baseline for comparison with potential options used to establish value for money.

SOC Option Recommendations Summary

The decision to either carry forward or discount each of the longlisted options, along with supporting reasons, are detailed in Table 9 above.

The Do Something options carried forward to OBC are defined in the Identified Shortlist section below, demonstrating how they have the potential to meet the Project Objectives:

- Option 1 Raised and upgraded highway wall (1% or 2% AEP SoP)
- Option 3 Purchase by Agreement

Three options were selected to be carried forwards as potential ‘add-ons’, to enhance the core options above:

- Option 2 Natural Flood Management
- Option 7 Property Flood Resilience
- Option 8 Debris Management

The remaining options were discounted:

- Option 4 Flood Warning System
- Option 5 Remove/improve Downstream Culvert
- Option 6 Offline Flood Storage / Reconnecting the flood plain
- Option 9 Reduce bed level of watercourse and culvert section
- Option 10 Widening of river channel
- Option 11 Raising property levels

The table below summarises the reasons for discounting each of these options, as described more fully in Table 9: Longlist Options Framework. Four of the options (Flood Warning System, Removal of Culvert, Offline Storage and Raised Property Levels) do not meet the Strategic Fit or Business Needs. Two have potential meet the Strategic Fit and Business Needs, but are considered unlikely to meet all CSF's (Reduce bed level and Widen Watercourse).

Table 10: Shortlist Option Assessment – Discounted Options

Longlist Option	**Reasons for being discounted**
Option 4 Flood Warning System	Does not meet Strategic Fit or Business needs, as it does not reduce risk. Not technically feasible to provide an NRW SLA service to the community. Any alternative would be novel or simplistic, and therefore unlikely to be effective.
Option 5 Remove/improve Downstream Culvert	Does not meet Strategic Fit or Business Needs, as it is unlikely to prevent internal property flooding in flood events exceeding the 3.33% AEP event (present day).
Option 6 Offline Flood Storage / Reconnecting the flood plain	Does not meet Strategic Fit or Business Needs, as it does not reduce flood risk in present day or in the future.
Option 9 Reduce bed level of watercourse and culvert section	Unlikely to meet Strategic Fit or Business Needs, as unlikely to provide significant reduction in present day or future flood risk. Achievability is likely to be low, and it may not match capacity and capability of potential suppliers. It is also unlikely to be affordable or to provide value for money. Overall, low potential to meet all CSF's.
Option 10 Widening of river channel	Unlikely to meet Strategic Fit or Business Needs, as significant volumes would be required to be excavated and unlikely to provide significant flood risk reduction in present day or in the future. Achievability and affordability is likely to be low. Supplier capability and capacity also likely to be low.

	High ecological impact. Does not align with SMNR principles. Overall, low potential to meet all CSF's.
Option 11 Raising property levels	Does not meet Strategic Fit or Business Needs, as it does not reduce flood risk in present day or in the future. Achievability, affordability, value for money, supplier capability and capacity are all likely to be very low. Overall, low potential to meet all CSF's.

Identified Short List

Shortlisted options have been carried forward from the longlist exercise. Table 11 shows the assessment made at SOC stage of each against the Project Objectives and Critical Success Factors; this reflects our understanding of the options at the conclusion of the SOC stage, and was in advance of recent OBC study findings. Most notably, at this stage in the appraisal it was anticipated that a hard defence to provide 1%AEP SoP (present day) would be circa 2.5-3m in height; following the updated modelling and RUA analysis, it is now expected to be 4m high or greater. This has subsequently impacted the viability of this option and it's potential to meet the project objectives, as described in the shortlist appraisal Table 31.

Option 1A, a defence wall with a 2% AEP SoP, has not been considered explicitly within the modelling and economic assessment. Instead, a high-level assessment has indicated whether this option has the potential to be economically viable. This assessment used an estimated reduction in costs associated with the lower wall height when compared with a 1% AEP wall and an estimate of the reduction in flood benefits associated with the lower SoP wall, to give an indicative assessment of the potential BCR for comparison.

Options are presented in no order of preference.

Table 11: Shortlist Option Assessment – Selected Options

Reference to:	**Option 1A**	**Option 1**	**Option 2**	**WAW**	**BAU**
Description of option:	Upgrade and raise existing highway wall **(2% AEP SoP)**	Upgrade and raise existing highway wall (**1% AEP SoP**)	Remove people & properties at high risk of flooding	Theoretical baseline where all flood risk activities ceased	Status quo continues
<u>Project Objectives</u>					
1.	Does reduce fluvial flood risk at the 16 properties up to **2% AEP.**	Does reduce fluvial flood risk at the 16 properties up to **1% AEP.**	Does reduce flood risk from all sources at the 16 properties for all flood events both now and in future.	Does not reduce flood risk to properties.	

2.	This option might mean that NRW adopts the re-built highway wall and takes on maintenance responsibility. However, potential for wall maintenance costs to be offset elsewhere, when considering other factors including post flood event expenditure, and potential for reducing other types of maintenance e.g. shoal removal. Other maintenance costs have potential to decrease.	This option has been investigated with two maintenance regimes. One where the existing regime is continued, and another where the maintenance regime is reduced by NRW.	Cessation of maintenance, therefore no ongoing maintenance costs.	Maintenance costs as existing, no anticipated reduction.
3.	Potential to contribute to the NRW well-being objectives. Improves community resilience to flooding in the short term however risk of exceedance due to climate change. Pollution to the natural environment as a result of urban flooding would be minimised.	Removes residents at highest risk but residual uncertainty over community (highway users and adjacent properties) resilience to flooding and climate change. However pollution to the natural environment as a result of highway and adjacent property flooding continues. Potential for wider benefits, including biodiversity net benefit and increased amenity space depending on how previously built-up land is used.	Does not contribute to any of the well-being objectives	Does not contribute to the well-being objectives.
4.	Resource intensive option. Typically raised defences can be effective to contain flooding however model uncertainty due to nature of upstream catchment presents challenge. Has	Potential to contribute to sustainable management of natural resources both in a local and wider scale.	Does not contribute to the sustainable management of	Does not contribute to the sustainable

	potential for wider benefits to be delivered.			natural resources.	management of natural resources.
Strategic fit and business needs	Reduces present day fluvial flood risk to the properties at Clydach Terrace in the 2% AEP event. There is potential that this option may not be able to meaningfully reduce fluvial flood risk in future due to combined impact of climate change and magnitude of freeboard assessed to be required in subsequent RUA.	Reduces present day fluvial flood risk to the properties at Clydach Terrace in the 1% AEP event There is potential that this option may not be able to meaningfully reduce fluvial flood risk in future due to combined impact of climate change and magnitude of freeboard assessed to be required in subsequent RUA.	Removes present day and future flood risk from all sources to the properties at Clydach Terrace. Residual risk to highway users and adjacent properties.	Does not resolve present day and future fluvial flood risk to the properties at Clydach Terrace.	Does not resolve present day and future flood risk to the properties at Clydach Terrace.
Potential achievability	Option is challenging technically feasible to manage flood risk due to scale of freeboard. This challenge increases following completion of RUA, which indicates a higher freeboard may be required than assumed at SOC. Site constraints will be considered and, any		Option is technically feasible to manage flood risk as long as all site constraints are considered and, any social and environmental detrimental impact is mitigated.	Option is achievable as current maintenance schedule would cease.	Option is achievable since current maintenance schedule would continue.

	social and environmental detrimental impact is mitigated.				
Supply-side capacity and capability	Option has potential to meet capacity and capability of potential suppliers. Further assessment is needed to determine buildability. Buildability is negatively impacted by subsequent RUA assessment during OBC which indicates greater wall height and extent may be required.			Capacity and capability of potential suppliers not relevant as maintenance ceases.	Option meets capacity and capability of potential suppliers since current maintenance schedule would continue.
Potential affordability	Option is potentially affordable in comparison to the associated future damage cost limitation. Further assessment is required to refine the costs.		Option is potentially affordable in comparison to the associated future damage cost limitation. Further assessment is required to refine the costs. Further discussions required with WG to understand whether FRM funding may be used for this purpose.	There would be a cost saving as the existing maintenance schedule ceases.	There would be no additional costs associated with maintenance or operation as existing regime continues.
Summary	Potential option	Potential option	Potential option		

Economic analysis – SOC Summary

The longlist comprised construction of a purpose-built FRM wall, downstream de-culverting, upstream natural flood management (NFM), installation of a Flood Warning System, offline flood storage, increasing the capacity of the watercourse, debris management, removal of properties at risk, property flood resilience (PFR) measures and raising the levels of existing properties. Options shortlisted on economic, technical, environmental and social feasibility, were taken forward for economic appraisal.

The SOC stage economic assessment in line with WG FCERM Business Case Guidance (FCERM-BCG[8]), determined the Present Value Damages (PVd), PVb and value for money in terms of a BCR, of the proposed FRM options using the information available at SOC stage. The economic assessment was undertaken using the simplified Rapid Assessment of Damages (RAD) tool, which is a simplification of the method prescribed for economic analysis in the MCM. The use of the tool was considered proportionate to the level of detail required for the SOC. Limitations of the RAD method include:

- Additional costs relating to the damage of vehicles, evacuation, risk to life, intangible impacts to health and emergency responses are reported on a "per residential property" basis. The tool does not provide any additional prescriptive guidance on the evaluation of these additional damages, and the "per property" value is therefore an average of expected costs from a range of property types.
- The tool focuses on determining residential property damages. It does offer an estimate of non-residential damages, but this is limited to the provision of a single non-residential sector average damage.
- The tool includes a high-level estimate of additional expenditure incurred by emergency services and organisations responsible for responding to flood events. The estimate is based on a 10% uplift to the "total property related damages".
- As advocated by FCERM-BCG, all property related damage are capped to the "risk free market value". However, the RAD tool uses generalised residential capping values that are derived using the Welsh national average house price based on the UK House Price Index (Land Registry, 2018). Therefore, the house prices are not necessarily reflective of the study area.
- The RAD tool methodology dilutes the assessment of risk to life and does not allow consideration of the lack of flood warning due to the challenges to provide timely flood warning in this upper catchment that has observed severe and rapid flooding. This leads to an underestimation of these damages and risks, particularly in the withdrawal option where there would be no flood warning available.

Additional to the use of the RAD tool, the biggest limitation of the SOC appraisal is that the 1 in 2 (50% AEP), 1 in 5 (20% AEP) and 1 in 10-year (10% AEP) events were not modelled for the shortlist options. This is because the proposed flood wall does not overtop until flood events exceeding the SoP event and therefore the risk of flooding from the Nant Clydach is removed for the lower order flood events.

However, as previously discussed there is a secondary flood mechanism of surface water flows being trapped behind the flood wall that are unable to discharge into the watercourse.

[8] Flood and Coastal Erosion Risk Management – Business Case Guidance, June 2019.

As these return periods have not been modelled, the assessment assumed that no properties are at risk of internal flooding from the residual pluvial risk in these scenarios. This assumption leads to potential overestimation of the benefits of the flood wall. The assumptions made, including the use of the RAD tool, and not modelling the lower order events, were considered appropriate for the previous SOC stage of assessment.

Table 12 presents a summary of the economic appraisal undertaken at SOC stage.

Table 12: Summary of SOC economic appraisal

Option	Total PVd (£k)	Total PVb (Relative to WAW) (£k)	Total PVb (Relative to BAU) (£k)	Total PVc (Relative to WAW) (£k)	Total PVc (Relative to BAU) (£k)	BCR (Relative to WAW)	BCR (Relative to BAU)	NPV (Relative to WAW) (£k)	NPV (Relative to BAU) (£k)
WAW	11,556	-	-	-	-	-	-	-	-
BAU	7,236	4,321	-	635	-	6.8	-	3,686	-
2% AEP SoP Wall	909	10,648	6,327	5,134	4,499	2.1	1.4	5,514	1,828
1% AEP SoP Wall	675	10,882	6,561	5,424	4,789	2.0	1.4	5,458	1,772
Purchase by agreement	4,289	7,268	2,947	6,900	6,265	1.1	0.5	368	-3,318

The SOC indicated that the wall option at both 2% and 1% AEP SoPs would provide a BCR >1. Conversely, the purchase by agreement option indicated a BCR <1, however it was recommended that this option was taken forward to OBC as:

- There are opportunities for the previously occupied land on Clydach Terrace to be used as recreational area with the potential for additional benefits that have not been explored at SOC.
- The option removes the residual hazard to the residents of Clydach Terrace. There is residual hazard in the wall option if the wall were to overtop in an exceedance event.

Economic analysis – OBC Summary

As part of this OBC assessment, a more detailed economic appraisal has been undertaken using the methodology outlined in the MCM[9]. The details of the economic appraisal are provided within the OBC Economics Report. A summary of the economic appraisal is provided below.

[9] FCERM: A Manual for Economic Appraisal, 2013 Flood Hazard Research Centre and Environment Agency

In comparison with the SOC, two options have been taken forward to modelling and economic analysis. These comprise the wall option at a 1% AEP SoP and the purchase by agreement option. The 2% AEP SoP was not taken forward as the two options at SOC stage had a similar BCR and therefore it was considered most appropriate to take forward the option with a higher SoP.

A high-level costing exercise determined whether there would be a significant reduction in wall costs if a 2% AEP SoP wall were chosen instead. The assessment indicated that the total wall costs would not decrease substantially, primarily because elements of the total cost including services diversions, road closures, RAW, traffic management and other high cost elements of the scheme would not be reduced by the lower wall height. Similarly, a high-level estimate of the benefits provided by the 2% AEP wall has also been undertaken so that an indicative BCR of a 2% AEP wall could be output for comparison. The results of this assessment are presented within the Economic Sensitivity section below.

The following sources of damages have been considered within the OBC economic analysis:

- Damages to residential and non-residential properties
- Emergency service costs
- Mental health costs
- Evacuation and temporary accommodation costs
- Risk to life
- Vehicle damages
- Intangible benefits to health

In line with HM Treasury Green Book guidance, the BAU option forms the economic baseline used to establish whether a given option represents value for money. The WAW option is used as an additional baseline for use in the economic assessment of FCERM projects. A summary of the assumptions made in the BAU* scenario are provided below:

- No blockage;
- No increase in shoal depth; and
- Vegetation clearance on going.
- Wall deterioration assumed to be 35 years to condition Grade 5 / failure.

**This is seen as an optimistic position assuming operational budgets can adapt accordingly.*

A summary of the assumptions made in the WAW scenario are similarly provided below:

- 67% blockage of the Ynysybwl tunnel;
- An increase in shoal depth of 0.5m; and
- No vegetation clearance.
- Wall deterioration assumed to be at 17.5 years to condition Grade 5 / failure.

Once the wall is assumed to have failed, it has been modelled as completely absent along its length. This worst-case scenario is appropriate due to the significant uncertainty in the known condition of the wall and its function. To estimate the rate of deterioration, Environment Agency guidance on asset deterioration and condition grade deterioration curves have been used. It is possible that the rate of deterioration for this specific asset may

not be reflected by the high-level information, however the assumptions used are considered appropriate.

A breach analysis has not been undertaken specifically as part of this assessment. If the wall were to fail, it is likely this would occur during a flood event when the wall is subject to loading due to the elevated water level. If a breach were to occur, localised velocities at the breach location are likely to be higher than in a scenario where either the wall overtops or where there is a more complete failure of the wall along its length. It is likely also that the speed of inundation may be higher at the start of the flood event in comparison to the two other scenarios mentioned. There is likely to be additional debris entrainment associated with the higher velocities of water rushing through the breach in the wall. However, it is assumed that the maximum flood depths at Clydach Terrace and elsewhere in the study area would not be significantly changed if a discrete breach were to occur due to the surrounding topography and typical flood mechanism wherein the “low spot” along Clydach Terrace fills to high depths once the wall either fails or is overtopped.

A model of the Nant Clydach and catchment has been used to inform the flood risk and economic damages within the study area. This model was originally produced in 2022 and comprises a linked 1D-2D ESTRY-TUFLOW model. The model uses a direct rainfall approach in order to explicitly represent the flow routing in the upper catchment. Due to the direct rainfall approach, the model is able to assess flood risk from both fluvial and surface water sources. Prior to the onset of the OBC modelling work, minor updates have been made to the hydraulic model, including:

- The TUFLOW software version was updated to use the latest available version (2023-03-AF-iSP-w64);
- The threshold level of a building at the southern end of Clydach Terrace has been corrected to 135.025mAOD, as it was previously input as 134.025mAOD

Additional checks were also performed to understand whether any of the input topographic data, which includes LiDAR and survey should be updated to more recent versions where available. The model already uses the latest LiDAR version as no additional LiDAR has been flown since the 2022 study and therefore no updates were necessary.

The update to the model software resulted in noticeable changes to the output flood depths in comparison to the previous model results. It was identified that the cause of the change in model results arises from changes to the sub-grid sampling (SGS) parameters between the previous and latest software versions. The 2023 software more effectively routes flow from the upper catchment to the Nant Clydach watercourse, increasing the flow within the river. The outcomes of the testing were agreed in December 2024. It was agreed that, as the use of the 2023 software results in a more conservative assessment of flood risk and this also adheres to typical modelling best practice, the most recent software version would be used for the OBC assessment.

A comparison exercise was not undertaken between the flooding observed in Storm Bert and the model outputs. The model has been verified previously against Storm Dennis, and the flooding observed in Storm Bert is consistent with that shown in the model, wherein the de facto wall is shown to overtop in low order events resulting in flooding to properties on Clydach Terrace.

These updates are described in more detail in the OBC Modelling Report.

An uplift to input rainfall has been applied to account for climate change over the 100 year design life of the project, in line with the available WG guidance[10]. The Central Estimate value of 10% has been applied in this study for years between 2025-2039, a 20% uplift has been applied to the years between 2040-2069 and a 25% allowance has been applied to the appraisal years between 2070-2125.

The following shortlisted options have been taken forward to economic analysis as part of the OBC.

Option 1 - Wall

The wall option that has been taken forward has a SoP of the present day 1% AEP event. As the SOC appraisal indicated that there is a residual risk of flooding associated with surface water ponding, PFR has been included in this option for those properties at risk both on Clydach Terrace and Windsor Place. The PFR measures are intended to mitigate the residual risk of pluvial flooding only.

PFR is effective at flood depths that are <0.6m. In the BAU scenario, once the existing highway wall overtops in the 5% AEP event, flood depths in properties on Clydach Terrace reach over 1.2 metres, and would therefore be too large for PFR measures. The use of PFR in isolation at Clydach Terrace is therefore not an appropriate standalone solution to mitigate fluvial flood risk arising from the Nant Clydach. To demonstrate this, Table 13 summarises the flood depths at each of the properties on Clydach Terrace in a 5% and 1% AEP event in the present day. The depths presented in this table are only indicative as they are based on hydraulic model outputs which are a representation of the potential real life scenario. The summary indicates that in the 5% AEP event most properties on Clydach Terrace experience flood depths in excess of 0.6m, and therefore PFR would not be suitable. In the 1%AEP event, PFR would not be suitable for any of these properties.

Table 13: Summary of modelled flood depths at properties within the study area in a 1% AEP event in the present day BAU scenario

Property	Indicative Flood depth (m)	
	5% AEP Event	1% AEP Event
1 Clydach Terrace	0.38*	1.09
2 Clydach Terrace	0.62	1.33
3 Clydach Terrace	0.74	1.44
4 Clydach Terrace	0.79	1.49
5 Clydach Terrace	0.95	1.65
6 Clydach Terrace	0.96	1.65
7 Clydach Terrace	1.27	2.06
8 Clydach Terrace	1.18	2.00
9 Clydach Terrace	1.14	1.96
10 Clydach Terrace	1.02	1.84
11 Clydach Terrace	0.91	1.73
12 Clydach Terrace	0.83	1.65

[10] Welsh Government, September 2021 *"Flood Consequences Assessments: Climate change allowances"* Accessed 22/01/2024 (Flood Consequences Assessments: Climate change (gov.wales))

13 Clydach Terrace	0.79	1.61
14 Clydach Terrace	0.69	1.51
15 Clydach Terrace	0.57*	1.39
16 Clydach Terrace	0.56*	1.37

* modelled flood depth is below 0.6m at these three properties, so it is possible that PFR may be effective in managing this flood risk. This may be flooding from either fluvial, pluvial or a combination of both sources.

When the SoP of the proposed wall is exceeded, either now or in future, flood depths are similarly >0.6m. As such, PFR is not appropriate for use to mitigate the residual risk of flooding that arises from overtopping or outflanking of the proposed wall structure. Further assessment of residual risk and hazard in an exceedance event is provided within this report.

Several Clydach Terrace properties have some form of PFR including floodgates and sandbags. However internal flooding to two properties was recorded during Storm Bert and therefore the distribution, performance and reliability of the existing PFR measures is assumed to be variable. It is not known whether airbrick covers or internal flood resilience measures have been incorporated. The cost estimate for the PFR does not take into account any existing PFR measures and is therefore likely conservative.

In the economic appraisal, the benefit of PFR installation has been incorporated by reducing damages by 75% for properties on Clydach Terrace and Windsor Place which experience internal flooding that is <0.6m deep. The damages are not reduced by 100% in order to account for possible failure of the PFR measures, for example if they were not put in place in time, as per MCM guidance.

Option 2 - Purchase by agreement

Two variations of the purchase by agreement option have been considered:

- **In combination with WAW assumptions:** It has been assumed that NRW would no longer continue to undertake maintenance of the Nant Clydach channel, as the 16 vulnerable properties on Clydach Terrace have been removed from the floodplain and are therefore no longer at risk. There is a risk that the hazard posed by flooding from the Nant Clydach to the remaining properties on Clydach Terrace, and to properties on Windsor Place is increased due to the cessation of maintenance.
- **In combination with BAU assumptions:** It has been assumed that NRW would continue to maintain the channel as they do currently. This assumption reduces the risk of disbenefit to third parties arising from the cessation of channel maintenance.

For the purchase by agreement in combination with WAW assumptions, the existing highway wall has an assumed residual life of 17.5 years, but this may be less in practice. If the wall fails or is washed away, RCTCBC would need to consider whether maintaining the highway is viable and how it would be defended. In this scenario, there is a residual risk of deep, fast flowing water in the highway. The residual hazard is considered further in the Options Analysis section. Additional public spend would be needed to manage the flood risk going forward, but it is considered that this would be outside of NRW remit and is not included at this time.

The purchase by agreement applies only to the 16 terraced properties along Clydach Terrace that experienced flooding during Storm Dennis. There are three additional properties on Clydach Terrace that are set back from the highway, at a higher level than the terraced properties. These properties are not shown to be at risk in the 1% AEP event in the present day epoch during the BAU scenario. Further, there is access to these properties to the rear from Other Street which could provide a safe evacuation route in a flood event.

In both purchase by agreement scenarios, it is assumed that no flood warning is in place for residents in Ynysybwl.

Two of the shortlisted options, the wall option and purchase by agreement in combination with WAW assumptions, have been modelled explicitly. The purchase by agreement in combination with BAU assumptions has not been modelled explicitly, and instead the BAU model outputs have been used to inform the flood damages in this scenario. The purchase by agreement with WAW assumptions modelling indicated that removal of the model representation of the buildings and re-naturalising the space had a negligible impact on flood risk elsewhere. As such, it was considered appropriate for the BAU with purchase by agreement economic option to use the BAU model results. All climate change scenarios have been modelled explicitly, so that the impact of climate change is better understood over the appraisal period.

Economic analysis – OBC Outputs

Table 14 below presents the capped present value (PV) damages for the economic baseline and option scenarios.

Table 14: Capped PV Damages

	WAW (£k)	**BAU (£k)**	**OP01 - 1% AEP SoP Present Day Wall with PFR (£k)**	**OP02a - Purchase by agreement WAW (£k)**	**OP02b - Purchase by agreement BAU (£k)**
Direct Residential Damage	4,702	4,185	1,543	2,428	1,912
Emergency Services Cost	522	131	127	241	75
Mental Health Cost	932	302	335	384	197
Relocation Cost	736	161	104	247	87
Risk To Life Cost	375	112	118	149	71
Vehicle Damage Cost	764	81	29	286	16
TOTAL	**8,031**	**4,971**	**2,256**	**3,736**	**2,357**

Table 15 below presents the PV benefits for the WAW and scheme option scenarios relative to the BAU scenario.

Table 15: PV Benefits relative to BAU

	WAW (£k)	OP01 – 1% AEP SoP Present Day Wall with PFR (£k)	OP02a - Purchase by agreement WAW (£k)	OP02b – Purchase by agreement BAU (£k)
Direct Residential Damage	-517	2,642	1,757	2,274
Emergency Services Cost	-391	5	-110	56
Mental Health Cost	-630	-33	-82	105
Relocation Cost	-575	56	-86	74
Risk To Life Cost	-263	-7	-38	41
Vehicle Damage Cost	-683	51	-205	65
Intangible Health Impacts	-4	-123	22	26
TOTAL	**-3,064**	**2,593**	**1,258**	**2,641**

The high flood damages shown in the Purchase by Agreement options is indicative of the fact that this option does not provide a flood benefit to other properties within the wider Ynysybwl area, such as those on Windsor Court and Windsor Place. Therefore, there are significant flood damages associated with other properties that are outside of the scheme. Additionally, the scheme removes flood risk only to those 16 properties which were flooded in Storm Dennis. In future epochs, with the impact of climate change, it is likely that the three set back properties on Clydach Terrace may experience flooding also. The inclusion of PFR for the properties on Windsor Place and Windsor Court in Option 1 also increases the benefits provided by the scheme relative to the Purchase by agreement options, where PFR would not be as appropriate as the scheme option does not reduce the risk of fluvial flooding, just removes some receptors.

Alongside the economic benefits presented previously, Table 16 summarises the reduction in the number of properties at risk associated with each option in the present day 1% AEP event. The assessment of hazard for a 1% AEP Wall has been undertaken using the DEFRA

Flood Hazard Rating FD2320/TR2 guidance. This assessment indicates that the wall option in combination with PFR significantly reduces the hazard posed by flooding at Clydach Terrace in the present day. In the purchase by agreement options, only the hazard posed to the 16 properties included within the scheme is removed. The other properties and the highway within the area remain at the same risk as they are in the BAU and WAW scenarios. It should be noted here that the 1%AEP SoP wall is assumed to be of the required height to provide protection against the 1%AEP flood event, and that this is likely to be higher than the 3m high wall that has been assumed for costing purposes. This is due to the higher freeboard allowance calculated by the RUA assessment that was completed in parallel with the economic assessment. It should also be noted that this property count is based on the data presented in the economic assessment, but has been refined to better reflect the hazard at each property; this approach is presented later in this report, above Table 34.

Table 16: Summary of number of properties within each hazard category in the present day 1% AEP event for the shortlisted options

	No. of properties				
Hazard rating	**BAU**	**WAW**	**Option 1 - 1% AEP SoP Present Day Wall with PFR *,****	**Option 2a - Purchase by agreement WAW**	**Option 2b - Purchase by agreement BAU**
Very low hazard – Caution	4	2	0	2	4
Danger for some – includes children, the elderly and the infirm	7	0	0	0	7
Danger for most – includes the general public	4	1	0	1	0
Danger for all – includes the emergency services	12	25	0	9	0

* The residual hazard from pluvial flooding shown in Figure 20 would be mitigated with the use of PFR.
** the wall is assumed to be the required height to provide protection in the present day 1%AEP flood event, i.e. it will be higher than the 3m high wall assumed for costing purposes.

More information is provided on the assessment of residual hazard in subsequent sections.

Cost estimates for the project options have been developed in association with a cost consultant. These costs comprise:

- A capital cost estimate, which has been inflated to 2027 prices based on the programme with Gateway 3 anticipated in 2027; and

- An ‘Other cost, based on high-level estimates for utilities diversions, road closures as well as the known unknowns such as NRW staff costs, consultancy fees and land compensations costs. These costs have then been discounted to 2027, the assumed start year of construction; and
- An optimism bias value of 44%, based on best practice recommended for OBC stage in the FCERM-BCG.

Table 17 summarises the estimate for construction costs. Sunk cost values are presented but are not included in the total construction cost estimate.

The cost estimates associated with OP01 – 1% AEP are based on the construction of a 3m high wall, which includes a nominal 750mm freeboard allowance. The residual uncertainty assessment, completed in parallel with the costing exercise, demonstrated that this nominal allowance is lower than the values indicated by the Residual Uncertainty Assessment, and so the costed 3m wall would not necessarily provide 1% AEP SoP given the inherent uncertainties in the hydraulic modelling. This is discussed further in the Residual Uncertainty allowance section. The required height of a wall to provide protection in the 1% AEP event in present day would be circa 4.5m, and would have a higher cost than indicated in the following tables.

Sunk costs have been updated since the Economic Appraisal Technical Report P04.

Table 17: Summary of Capital cash costs

Element	OP01 - 1% AEP SoP Present Day Wall with PFR (£k)*	OP02a - Purchase by agreement WAW (£k)	OP02b - Purchase by agreement BAU (£k)
Sunk Costs (Initial Assessment to SOC and SOC to OBC)			
Sunk Costs	390	390	390
OBC to FBC cost Estimates			
NRW staff	83	101	101
Site Investigation & Survey	54	23	23
Consultant fees	334	127	127
Other costs	5	8	8
Option FBC to Completion Estimates			
Contractor fees	2,702	976	976
NRW staff	112	37	37
Consultant fees	54	20	20
Site supervision	130	44	44
Other costs	239	2,437	2,437

Total project cost (excl sunk cost & Optimism Bias)	3,801	3,865	3,865

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP in present day is circa 4.5m, which will incur higher costs.

The whole life costs are presented in Table 18. An optimism bias value of 44% has been applied at this stage, however this value is subject to review following a risk workshop and qualitative risk assessment, which would be undertaken at a future stage (FBC), if a preferred option is chosen and the project taken forward.

Table 18: PV Whole Life costs (£k)

Present Value (PV) Costs	**OP01 - 1% AEP SoP Present Day Wall with PFR (£k)***	**OP02a - Purchase by agreement WAW (£k)**	**OP02b - Purchase by agreement BAU (£k)**
PV Non-Construction Costs	1,007	2,762	2,762
PV Construction Costs	2,710	979	979
PV Environmental Costs	0	0	0
PV Maintenance	194	0	0
Optimism Bias (44%)	1,534	1593	1593
PV Whole Life Costs	**5,531**	**5,333**	**5,333**

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP in present day is circa 4.5m, which will incur higher costs.

The PV whole life costs, PV benefits and the Net Present Value for each of the options is provided in Table 19, alongside the BCR of each option relative to BAU. The PV costs are based on cash costs, inflated to the year that they are expected to be incurred and then discounted to present day values. The PVb represent the difference in damages between the proposed option and the BAU scenario. The project costs are then used to calculate the BCR as well as the Net Present Value (NPV) of each option.

Table 19: Option net present values & benefit cost ratios

	OP01 - 1% AEP SoP Present Day Wall with PFR (£k)*	**OP02a - Purchase by agreement WAW (£k)**	**OP02b - Purchase by agreement BAU (£k)**
PV Benefits	2,593	1,258	2,641
PV Whole Life Costs	5,531	5,333	5,333
Net Present Value (NPV)	-2,938	-4,075	-2,692
BCR	**0.47**	**0.24**	**0.50**

*costs and BCR shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP in present day is circa 4.5m, which will incur higher costs and a lower BCR.

Whole Life Carbon Costs

An estimation of the carbon cost associated with the shortlisted options has been made using the LIT 14605 Carbon Modelling Tool (CMT) v8.1, which was most recently updated in 2023.

The CMT was originally produced by the Environment Agency (EA) and was subsequently adopted for use in Wales by NRW. The CMT is intended to help inform a high-level estimate of the carbon footprint of different options, particularly in comparison to each other. The assessment has been undertaken at a high-level, noting that at this stage of assessment, the details of the specific construction approach and timescales for construction have not been determined.

The carbon cost associated with each option is broken down into different contributing factors, including:

- Capital carbon
- Operational carbon
- Replacement carbon
- Refurbishment carbon
- Demolition carbon
- Residual carbon

These individual contributors are summed to give a Whole Life Carbon (WLC) cost, in tonnes of CO2 equivalent.

For the wall option, the “Non-tidal Wall – Retaining – Concrete” asset type within the CMT was considered the best match to the proposed scheme. For this asset, the CMT requires that an estimated volume of the proposed wall is provided for the calculations. The cross-sectional area of the wall is 3.06m^2. Multiplied by the length of the wall (270m), this gives a total approximate wall volume of 826m^3.

The purchase by agreement option is novel and falls outside of the typical assets and activities that are normally built or undertaken as part of a FRM scheme. Within the CMT there is no asset type that closely corresponds to the purchase by agreement option.

The Carbon Calculator (LIT 14604 v6.1 2023) tool has instead been used to estimate a whole life carbon cost for the purchase by agreement option. The carbon calculator tool allows for greater flexibility than the CMT as it allows for input of various parameters associated with transport, waste material and plant use for the option.

At OBC stage, the details of the demolition of the buildings and the timescales of the scheme have not been determined. This would be considered in more detail if the project, and this option, progressed to Full Business Case (FBC) stage. Therefore, a significant number of assumptions were made to derive suitable parameters for input to the tool.

Carbon costs for the purchase by agreement option have been estimated for the following factors:

- Imported topsoil for landscaping
- Waste disposal distance and volume of material for disposal
- Plant procurement and transport to site
- Use of plant
- Transport of site personnel

Within the Carbon Calculator tool, these factors fall within the Capital Carbon (A1-A5) category. High-level estimates of each of the above factors have been input to the Carbon Calculator tool. Further information regarding the specific estimates made are presented within the Whole Life Carbon Costing Technical Note, included as a Product with this report.

The outputs from the CMT modelling tool are presented within Table 20.

Table 20: Carbon modelling tool summary

Stage	**Option 1 – 1% AEP SoP Present Day Wall with PFR ***	**Option 2 – Purchase by Agreement**
Capital carbon (A1-A5) (tCO2e)	1,315	120.1
Operational carbon (B1-B3) (tCO2e)	54	N/A
Replacement carbon (B4) (tCO2e)	768	N/A
Refurbishment carbon (B5) (tCO2e)	28	N/A
Demolition carbon (C) (tCO2e)	176	N/A
Residual carbon (D) (tCO2e)	-241	N/A
Whole life carbon (tCO2e)	2,341	120.1
Whole life carbon – slope uncertainty (%)**	20	N/A (No slope uncertainty is available as the purchase by agreement option has used values estimated from the Carbon Calculator Tool, rather than using the

Stage	Option 1 – 1% AEP SoP Present Day Wall with PFR *	Option 2 – Purchase by Agreement
		project data within the CMT).

*Carbon values shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP in present day is circa 4.5m. This will have higher values.

**Slope uncertainty is the range within the correct value may be found by considering variations in the carbon data. A higher slope uncertainty indicates a higher variation in carbon outputs for an asset of the same type.

The CMT is intended for high-level appraisal and the relative comparison of the carbon cost associated with different options. The limitations of this study are provided below:

- The carbon rates and values within the CMT are generally based on English projects and so some variations in rates could be seen between these projects and those undertaken in Wales
- Ynysybwl is located in a relatively rural area, and therefore there may be some difficulties associated with transport of material/plant or finding a suitable location for waste disposal
- The assessment of the volume of the wall asset within the wall option is based on its height with a nominal freeboard. The Residual Uncertainty Assessment (RUA) indicated that to provide increased confidence in the protection provided by the wall, both its height and length may need to be increased substantially. This would increase the carbon cost associated with the wall.
- As detailed above, for the purchase by agreement option there are a number of assumptions that have been made to input to the Carbon Calculator tool. At this stage of assessment, the methodology and programme for undertaking the scheme have not been determined, and therefore the carbon cost is based on very high-level estimates only.

The assessment has indicated that Option 1, the wall option, has a much larger relative carbon cost when compared to the other option, Option 2, purchase by agreement.

The large difference in carbon costs is mainly associated with the fact that one option involves building a large, concrete asset with all associated material, excavation, construction and material removal costs. Although the purchase by agreement option would involve the use of plant and the removal of a relatively large amount of material, as no new FRM asset is created it is estimated that the overall carbon associated with this would be much lower.

It is recommended that if the project progresses to FBC stage, the Carbon Calculator tool should be used to refine the carbon cost associated with the options once further details regarding the construction methodology and whole life arrangements are known.

Economic analysis – OBC Conclusion

The economic appraisal indicates that each of the potential options for a flood scheme at Ynysybwl has a BCR that is <1. This indicates that the estimated costs for the scheme are larger than the calculated flood benefits.

Of the three options that have been considered, the BCR of the purchase by agreement option in combination with BAU assumptions is highest, at 0.50. This reflects the assumption that with ongoing maintenance, the risk of flooding from the Nant Clydach is less severe for residual receptors in the study area than in the scenario where maintenance is ceased.

The BCR of the 1% AEP SoP wall option is second highest, at 0.47. This reflects the provision of a 1% AEP SoP in the present day, with PFR measures being used to protect against the secondary flood risk posed by pluvial flooding. These options only work in combination. As discussed previously, the flood depths even in lower order fluvial events are >0.6m and could therefore not be mitigated by PFR alone.

The purchase by agreement option in combination with WAW assumptions has the lowest BCR of the three options, at 0.24. When the WAW assumptions are in place, flooding from the Nant Clydach causes flood damages to properties on Windsor Place even in relatively low order events, reflecting the significant residual risk of flooding from the watercourse in this scenario.

The high flood damages shown in the purchase by agreement options is indicative of the fact that this option does not provide a flood benefit to other properties within the wider Ynysybwl area, such as those on Windsor Court and Windsor Place. Therefore, there are significant flood damages associated with other properties that are outside of the scheme. Additionally, the scheme removes flood risk only to those 16 properties which were flooded in Storm Dennis. In future epochs, with the impact of climate change, it is likely that the three set back properties on Clydach Terrace may experience flooding also. The inclusion of PFR for the properties on Windsor Place and Windsor Court in Option 1 also increases the benefits provided by the scheme relative to the Purchase by agreement options, where PFR would not be as appropriate as the scheme option does not reduce the risk of fluvial flooding, just removes some receptors.

A comparison is made in Table 21 between the economic output values at SOC and those produced at OBC stage.

Table 21: Comparison of SOC and OBC economic outputs. Note that only BAU, Op01 1% AEP and Op02 with WAW assumptions have been included in the comparison for consistency between the options at SOC.

	SOC			**OBC**		
	BAU	**OP01 – 1% AEP Wall**	**OP02a – Purchase by Agreement WAW**	**BAU**	**OP01 – 1% AEP Wall***	**OP02a – Purchase by Agreement WAW**
PV Damages (£k)	7,236	675	4,289	4,971	2,256	3,736

PV Benefits (£k)	-	6,561	2,947	-	2,593	1,258
PV Whole Life Costs (£k)	635	4,789	6265	-	5,533	5,333
Net Present Value (NPV) (£k)	-	1,772	-3318	-	-2,938	-4,075
BCR	-	1.4	0.5	-	0.47	0.24

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

The calculated damages for the baseline scenarios (BAU and WAW) are lower in the OBC assessment than in the SOC. The larger damage values at SOC primarily relates to the use of the RAD tool at the previous stage of the assessment.

The RAD tool uses national average property prices to inform the cost of a property and therefore the damage values it can accrue, so if property prices in reality are lower in the assessment region this can lead to overestimation of damages. Additionally, where low depths are present, such as when there is the residual pluvial risk in this study, the RAD tool overestimates flood damages due to the binary nature of the tool wherein a property is either classed or flooded or not, and the depth of flooding is not accounted for.

Similarly, the calculated benefits for the scheme options are reduced relative to the assessment undertaken at SOC. At SOC stage, the model was not run for events lower than the SoP provided by the wall options (present day 2% AEP and 1% AEP). This was because the fluvial flood mechanism of wall overtopping would not occur in events lower than the SoP provided by the wall. However, this assumption meant that damages related to residual pluvial flooding were not accounted for within the damages for the wall options. This lead to an overestimation of the flood benefit for these options. In the OBC economic appraisal, the lower order events have been modelled explicitly and the results included in the economic assessment. As such, the damages related to pluvial flooding in lower order events is captured in the options appraisal.

The economic appraisal has been undertaken in accordance with the latest HM Treasury Green Book guidance. Detailed hydraulic modelling has been undertaken to assess the flood damages and benefits associated with each option using an NRW-accepted model from 2022. Updates have been made to the model to ensure its continued suitability for use in this study, including updating the software version to the latest available. Climate change has been modelled explicitly, so the increase in flood damages over the appraisal period is also assessed. Unlike at the SOC stage, all return periods used in the economic assessment have been modelled and therefore damages related to pluvial flooding in lower order events has also been represented explicitly. Threshold survey has been obtained for the properties within the study area and this has been used to inform the level at which internal property flooding would occur in the economic appraisal. It is considered that this economic appraisal uses the latest available data and methodologies. Further survey, modelling or economic appraisal would be unlikely to materially change the outcome of this study.

Economic analysis – Sensitivity testing

A series of sensitivity analyses have been undertaken to assess the robustness of the economic analysis. The following metrics have been varied:

- Increase and decrease in PV benefits (+/-20%);
- Increase and decrease in PV costs (-20%);
- Decreasing costs until options reach BCR threshold of 1;
- Reduced construction costs based on alternative construction approach; and
- Reducing the SoP provided by the wall option to a 2% AEP event.

Table 22 and Table 23 present the results for the PV benefits and PV costs sensitivity tests, respectively.

When the PV benefits for the schemes are increased by 20%, the scheme BCRs increase proportionally. However, the BCR for all schemes is still <1. There may be additional wider benefits of the schemes in terms of NBB or amenity benefit that are not currently quantified, however it is considered unlikely that these additional benefits would amount to a 20% increase, and further additional benefits would be required for any scheme to have a BCR >1.

The sensitivity tests indicate that when PV costs are reduced significantly, there is an increase in the BCR values for the options indicating that they are closer to achieving economic viability, however the values remain below 1. Depending on the final optimism bias chosen, there is the potential that this reduction in costs could be achieved, however a more significant reduction would be required for the BCR to be >1 for any option.

Table 22: Sensitivity Analysis – Increase and decrease in PV benefits (+/-20%)

Sensitivity Analysis – PVb + 20%					
OP01 - 1% AEP SoP Present Day Wall with PFR *		**OP02a - Purchase by agreement WAW**		**OP02b - Purchase by agreement BAU**	
PV Benefits (£k)	3,111	PV Benefits (£k)	1,510	PV Benefits (£k)	3,169
PV Cost (£k)	5,531	PV Cost (£k)	5,333	PV Cost (£k)	5,333
BCR (relative to BAU)	0.56	BCR (relative to BAU)	0.28	BCR (relative to BAU)	0.59
Sensitivity Analysis – PVb - 20%					
OP01 - 1% AEP SoP Present Day Wall with PFR *		**OP02a - Purchase by agreement WAW**		**OP02b - Purchase by agreement BAU**	
PV Benefits (£k)	2,074	PV Benefits (£k)	1,007	PV Benefits (£k)	2,113
PV Cost (£k)	5,531	PV Cost (£k)	5,333	PV Cost (£k)	5,333

BCR (relative to BAU)	0.38	BCR (relative to BAU)	0.19	BCR (relative to BAU)	0.40

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

Table 23: Sensitivity Analysis – Increase and decrease in PV costs (+/-20%)

Sensitivity Analysis – PVc + 20%					
OP01 - 1% AEP SoP Present Day Wall with PFR *		**OP02a - Purchase by agreement WAW**		**OP02b - Purchase by agreement BAU**	
PV Benefits (£k)	2,593	PV Benefits (£k)	1,258	PV Benefits (£k)	2,641
PV Cost (£k)	6,637	PV Cost (£k)	6,400	PV Cost (£k)	6,400
BCR (relative to BAU)	0.39	BCR (relative to BAU)	0.20	BCR (relative to BAU)	0.41
Sensitivity Analysis – PVc - 20%					
OP01 - 1% AEP SoP Present Day Wall with PFR *		**OP02a - Purchase by agreement WAW**		**OP02b - Purchase by agreement BAU**	
PV Benefits (£k)	2,593	PV Benefits (£k)	1,258	PV Benefits (£k)	2,641
PV Cost (£k)	4,425	PV Cost (£k)	4,266	PV Cost (£k)	4,266
BCR (relative to BAU)	0.59	BCR (relative to BAU)	0.29	BCR (relative to BAU)	0.62

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

Table 24 presents the results for the sensitivity test where the costs are decreased until the scheme meets the BCR threshold of 1. For Op01, a reduction in whole life costs of 53% would be needed for the BCR for the scheme to be >1. For the Purchase by agreement options, a reduction in whole life costs of 77% and 51% would be needed for the purchase by agreement option in combination with the WAW and BAU assumptions, respectively.

Table 24; Sensitivity testing - Decrease in costs to meet the BCR threshold

	OP01 - 1% AEP SoP Present Day Wall with PFR (£k)*	**OP02a - Purchase by agreement WAW (£k)**	**OP02b –Purchase by agreement BAU (£k)**
Whole life cost (£k)	5,531	5,333	5,333
PV benefit (£k)	2,593	1,258	2,641
Percentage of whole life cost	47%	23%	49%
Altered whole life cost (£k)	2,599	1,227	2,613
Whole life cost difference (£k)	2,931	4,106	2,720
NPV	-7	32	28
BCR	1.00	1.03	1.01

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

A high-level cost exercise determined whether the use of an alternative form of wall construction would improve the economic viability of the option. In contrast to the standard option, which is a reinforced concrete wall, the alternate approach uses pre-cast concrete blocks that interlock to form the wall, similar to that used at Tregaron.

At this stage a 2m wide concrete slab has been assumed for the blocks to sit on. The block dimensions are 1.2m long, 0.8m wide and 0.4m high. To form the base of the wall, 3 rows of 2 blocks would be used to form the 1.2m high base. Above this, a single line of blocks that is 5 rows high would be added on top, so the approximate total wall height is 3.2m. The cost estimate is based on fair face blocks with an allowance for a formed finish.

The main limitations and concerns with the approach include:

- The cost estimate provided is based on a high-level assumption of the number of blocks needed, and this would need to be confirmed by a specialist contractor.
- Additional measures may be required to ensure stability that have not been costed.
- The block wall would have a larger footprint in comparison to the RC wall and take-up a larger proportion of the riverbank area. There would be less opportunity to reinstate the riverbank and result in permanent land-take, reducing the width of the riparian corridor and negatively impacting biodiversity.
- The use of a precast solution means that there is less flexibility in the wall height as the blocks come in standard sizes.
- There may be a detrimental visual impact of using the block construction method. A bespoke mould may be required for the top of the wall.

- The required foundations would be the same as for the RC wall. Therefore, there would still be the same temporary works issues regarding management of water during the build process.

- There is additional complexity from ensuring each block joint is watertight with high maintenance requirements for the scheme lifetime. Maintenance costs would exceed those associated with the RC wall, however at this stage of assessment, the same maintenance costs have been used for the legato block wall as for the RC wall. It is likely that in reality, the higher maintenance costs associated with the PCC block wall would decrease the viability of this construction method.

The whole life cost of building the wall using this approach has been estimated at £4,159k. This is £1,372k less than estimated using an RC wall. Table 25 summarises the PV benefits, costs and BCR for the block construction approach. The same values for the RC wall approach are also provided for comparison.

Table 25: Sensitivity test for use of PCC block construction approach

Option	PVd (£k)	PVb (£k)	PV Whole Life Costs (£k)	NPV	BCR
1% AEP Wall (RC Wall)*	2,256	2,593	5,531	-2,938	0.47
1% AEP Wall (PCC Wall)*	2,256	2,593	4,159	-1,567	0.62
Purchase by Agreement WAW	3,736	1,258	5,333	-4,075	0.24
Purchase by Agreement BAU	2,357	2,641	5,333	-2,692	0.50

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

The sensitivity test indicates that using an alternative construction approach, including the use of PCC blocks, could improve the BCR of the wall option so that it is 0.62 rather than 0.47. At this stage of assessment, the detailed construction methodology, viability and maintenance requirements for a PCC block wall have not been explored fully and therefore the PV cost for the PCC block wall presented above may underestimate the true cost of this option. However, the sensitivity test indicates that the BCR for the scheme is still <1 and does not provide value for money.

As an alternative to the 1% AEP wall option, the flood benefits and damages of a 2% AEP SoP wall were estimated. This was a very high-level estimate of the option and did not include any additional modelling to estimate any residual flood depths at Ynysybwl once the wall was overtopped in events larger than a 2% AEP. The damages from this option are estimated from the 1% AEP models. This provides an overestimation of damages but is considered acceptable because of the highly constrained topography along Clydach Terrace that results in largely similar flood extents between different flood return periods where overtopping of the wall occurs.

The assessment presented in Table 26 below is purely for comparative purposes, to indicate whether there would be any significant benefit in terms of BCR if a lower wall height, providing a lower SoP, was assessed.

Table 26: Sensitivity testing - 2% AEP Wall

Option	PVd (£k)	PVb (£k)	PV Whole Life Costs (£k)	NPV	BCR
1% AEP Wall*	2,256	2,593	5,531	-2,938	0.47
2% AEP Wall**	3,989	1,043	5,442	-4,399	0.19
Purchase by Agreement WAW	3,736	1,258	5,333	-4,075	0.24
Purchase by Agreement BAU	2,357	2,641	5,333	-2,692	0.50

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

**costs are shown for a wall with 750mm freeboard; RUA has not been completed for this scenario, but it is unlikely to be sufficient and the actual required wall height would be higher. This will have higher costs and lower NPV and BCR.

The high-level assessment indicates that a 2% AEP wall is not economically viable. The lower BCR of 0.19 relative to the 1% AEP SoP wall BCR of 0.47 reflects the increased flood damages if the wall height were lowered. The reduction in wall costs associated with the reduced amount of material required to build a lower SoP wall is minor relative to the costs that remain largely unchanged, including utility diversions, roadworks etc.

The maintenance costs associated with the BAU option are not included in the main assessment, but have instead been assessed as an additional sensitivity scenario. The maintenance costs are identified and tested as follows:

- Maintenance of highway wall and drainage apparatus, for the estimated residual life of the asset: excluded, as these costs are incurred by Others and so are not part of the FRM appraisal.

- De-shoaling of the river channel adjacent to Clydach Terrace: estimated to cost £18k per visit, with one visit every three years. It is noted that, going forwards, this would be reactive i.e. undertaken in response to trigger levels being reached, and the cost would be impacted by the availability of a suitable disposal site.

Table 27: Sensitivity testing – De-shoaling costs

Option (with de-shoaling)	PVd (£k)	PVb (£k)	PV Whole Life Costs (£k)	NPV	BCR
BAU	4,971	n/a	263	n/a	n/a
1% AEP Wall*	2,256	2,593	5,794	-3,201	0.45

Purchase by Agreement WAW	3,736	1,258	5,333	-4,075	0.24
Purchase by Agreement BAU	2,357	2,641	5,596	-2,955	0.47

*costs shown are for a 3m high wall. The subsequent RUA has shown that the wall height required to provide 1%AEP SoP is circa 4.5m. This will have higher costs and lower NPV and BCR.

The high-level assessment indicates that the inclusion of de-shoaling costs does not materially impact the BCR of the affected options. The BCR of the Purchase by Agreement BAU option remains marginally higher than 1%AEP Wall.

Project costs and delivery of do-something options

A financial breakdown including a summary of sunk costs and costs to deliver the FBC and scheme including closure is provided in Table 28 of do-something options.

Table 28; Financial breakdown for do-something options

Case Stage	**Cash Costs (£s)**
Sunk Costs under current total approval of £492,415	
Strategic Outline Case	134,000
Outline Business Case	256,000
Sunk Cost Total	**390,000**
Full Business Case	692,000
Delivery	4,771,000
Closure	9,000
Total Future Cost	**5,472,000**

Indicative project costs to proceed with either Option 1 or Option 2 are shown in Table 29 below. This shows a cost breakdown of the following stages, consisting of FBC and Delivery. Sunk costs up to end of March 2025 (up to the end of 24/25) are also shown only for reference. This is reflective of achieving the FBC milestone of 28/02/2027 with then construction profiled over two summer periods during 2027 and 2028 due to anticipated environmental permitting constraints.

Table 29: Project costs (£)

	Sunk SOC, OBC	**Year 1 FBC**	**Year 2 FBC**	**Year 3 Delivery**	**Year 4 Delivery**	**Year 5 Closure**
Year	**To 24/25**	**25/26**	**26/27**	**27/28**	**28/29**	**29/30**
Chargeable staff costs (internal)	91,000	41,000	41,000	56,000	50,000	6,000
Site Investigation and Surveys	12,000	27,000	27,000	-	-	-
Consultant Fees	287,000	169,000	169,000	93,000	90,000	3,000
Delivery (do something)	-	-	-	1,470,000	1,470,000	-
Inflation	0	0	6,000	41,000	41,000	-
Risk contingency	-	105,000	107,000	730,000	730,000	-
Sub Total (total costs which require funding)	390,000	342,000	350,000	2,390,000	2,381,000	9,000
Internal staff cost		10,000	12,000	4,000	4,000	1,000
Total cost of project including staff time	**390,000**	**352,000**	**362,000**	**2,394,000**	**2,385,000**	**10,000**

The timescales associated with the various project and delivery milestones are presented in Table 30.

Table 30: Summary of timescales for project milestones for do-something options

Milestones	Date	Comment
Gateway 3 – Approved for delivery	28/02/2027	FBC
Gateway 4 – Delivery Handover Completion	30/11/2028	Inclusive of construction (subject to third party approvals and constraints)
Gateway 5 – Project Closure	30/11/2029	12 months defects period

Procurement requirements

Delivery of the project would require a subsequent procurement exercise for the Full Business Case (FBC) phase involving detailed design including ground investigation and associated surveys. Should the FBC receive approval and assurance, the subsequent construction stage will require procurement of a contractor.

Procurement strategy

If Option 1 or 2 were to be progressed, detailed Design consultancy services to inform the FBC would be procured via the NRW WCS Framework Consultancy Lot. Services would be secured via a NEC4 Option E (Target cost setting) and Option C (scope delivery) Professional Services Contract (PSC).

Ground investigation to inform the detailed design would be procured via NRW's Next Generation Ground Investigation Framework. Ground investigation with these services secured via an NEC4 Engineering and Construction Short Contract (ECSC).

When and as required, subject to approval of the FBC, the main contractor would be procured via a suitable Construction Framework that is available at the time.

NRW's proposed procurement strategy for the Full Business Cases would use the existing WCS Framework for consultancy services, or the use of SEWTAPS. This is a continuation of the procurement strategy for the OBC.

Key Contractual Issues

Delivery of any solution would be subject to constraints stipulated in licensing and permits. We expect this would include phasing of the works to ensure flood risk is managed at all times, avoiding near/in-river fisheries embargo periods between October and March, and minimising impact on residents and highway users. This would likely to result in a longer construction period and with it exposure to volatility in pricing and contractor risk including accounting for the effects of inflation.

Options Analysis – Short List Table ⓘ

The following table provides a comparison between various parameters and values associated with each option. The cost estimates associated with OP01 – 1% AEP are based on the construction of a 3m high wall, which includes a nominal 750mm freeboard allowance. The residual uncertainty assessment, completed in parallel with the costing exercise, demonstrated that this nominal allowance is lower than the values indicated by the Residual Uncertainty Assessment, and so the costed 3m wall would not necessarily provide 1% AEP SoP given the inherent uncertainties in the hydraulic modelling. This is discussed further in the Residual Uncertainty allowance section. The required height of a wall to provide protection in the 1% AEP event in present day would be circa 4.5m, and would have a higher cost than indicated in the following table.

Table 31: Short List Appraisal Summary Table

	Business As Usual (BAU)	**Option 1 – 1% AEP SoP Present Day Wall with PFR**	**Option 2 – Purchase by agreement WAW**	**Option 2 – Purchase by agreement BAU**
Public Sector Cost (or appropriate value for cost)	-	£5,531k	£5,333k	£5,333k
Appropriate cost benefit Ratio	-	0.47	0.24	0.50
Significant unmonetisable costs/benefits	Significant day by day impact on residents from financial, practical and emotional strain of flood risk and	The wall is likely to be imposing and significantly impact of views/light for properties on Clydach Terrace. Initially option better protects the community however over time the likelihood of hazardous overtopping increases.	Option reliant on all affected residents agreeing to a potentially disruptive relocation. There is an unmonetisable cost to the community associated with the relocation of residents, many of whom may have lived in the area for a substantial period. This may weaken community ties in Ynysybwl. Addresses properties and people most at risk, but hazard to highway users and over time the wider community as baseline.	

	Business As Usual (BAU)	Option 1 – 1% AEP SoP Present Day Wall with PFR	Option 2 – Purchase by agreement WAW	Option 2 – Purchase by agreement BAU
	prolonged uncertainty.		In the absence of BAU measures, faster deterioration in hazard to highway users and the wider community.	
Significant unquantifiable benefits / disbenefits	Deteriorating condition and residual life of the de facto highway wall.	Improvements to mental health and wellbeing of residents due to reduction in flood risk.	Improvements to mental health and wellbeing of residents due to reduction in flood risk. Potential opportunity for wider amenity benefits through provision of educational or recreational space in previously occupied area.	
Risk cost	-	Risk register costs have not been allocated. A standard Green Book risk value (optimism bias) of 44% has been applied. The cost estimate based on a 1% AEP flood level plus 0.75m freeboard. However, significant uncertainties from gauge data and model parameters suggest a minimum additional height of +1.2m (and corresponding increase in length - see RUA below). Design development likely to increase height and	Risk register costs have not been allocated. A standard Green Book risk value (optimism bias) of 44% has been applied. The option is relatively simple from a construction feasibility perspective. The optimism bias may overestimate uncertainty in construction costs. However the option is a novel approach to FRM and has uncertain legal considerations.	

	Business As Usual (BAU)	Option 1 – 1% AEP SoP Present Day Wall with PFR	Option 2 – Purchase by agreement WAW	Option 2 – Purchase by agreement BAU
		length, raising costs and buildability considerations. No quantified risk allowance has been included despite such as works in proximity to buried utilities that may require more costly diversions or subsequent ground investigations encounter unforeseen features not identified by the available desk study.		
Residual optimism bias (if applicable)	-	44%	44%	44%
Switching values of key variables	-	20% +/- option costs and benefits resulted in BCR <1	20% +/- option costs and benefits resulted in BCR <1	20% +/- option costs and benefits resulted in BCR <1
Life span of option	-	100 years	100 years	100 years
Net Present Social Value	-	-£2,938k	-£4,075k	-£2,692k

In addition to the economic analysis discussed previously and summarised in the table above, other factors have been considered to further refine and assess each of the shortlisted options.

Option 1 – Wall: Residual Uncertainty Analysis

A Residual Uncertainty Analysis (RUA) has been undertaken to define the amount of freeboard that would be required to improve the confidence in the provision of the design SoP by the wall option. A wall height, with no freeboard (2.25 metres), represents a 0% Confidence Interval (CI), and therefore there is a 50% chance of exceedance in the design event. The RUA has been undertaken in accordance with the latest Tier 1.5 guidance produced by the Environment Agency, Assessment of Residual Uncertainty - Supplementary Technical Guidance[11].

Previous sensitivity testing, information from NRW regarding the existing maintenance regime and anecdotal information regarding blockages potentially present during previous flood events have been used to define the model parameters which are considered to impact the modelled water levels most significantly. These parameters comprise:

- 1D roughness value
- 2D roughness value
- Input rainfall and baseflow values (grouping together uncertainties in the modelled assessment including the rainfall loss modelling approach, depth varying roughness approach and grid approach as these factors tend to influence the model routing which in turn influences the amount of flow within the channel)
- Blockage of the Ynysybwl tunnel
- Siltation of the channel
- Blockage of the channel

An estimate of the variation in these parameters corresponding to different CIs has been made based on available literature, NRW guidance documents and information regarding the behaviour of the catchment during previous flood events. The 68% and 95% CIs have been assessed as part of the RUA. These CIs correspond to a probability of exceedance of 15.9% and 2.3%, respectively.

Initial model testing was undertaken by varying the parameters by the chosen 68% CI values to determine which parameters have the most impact on the primary variable, the water level in the Nant Clydach adjacent to Clydach Terrace in the design SoP of the 1% AEP event.

At the 68% CI, the most impactful parameters are shown to be: 1D roughness, blockage of the Ynysybwl tunnel and the input rainfall. Of these three, the input rainfall is by far the most impactful, resulting in water level increases between 1.93-2.46m along the length of the wall.

Blockage of the channel and siltation within the channel were shown to have a minor impact on water levels in the channel, with a maximum increase in levels of 0.04m.

[11] LIT 73536 - Assessment of Residual Uncertainty Supplementary Technical Guidance, Environment Agency April 2024

The most impactful parameters in the initial 68% CI testing were taken forward to further modelling at 95% CI and subsequently used within the Tier 1.5 assessment. Those parameters which are less impactful have not been taken forward to the Tier 1.5 assessment.

Four parameters were taken forward to further modelling analysis and subsequently the Tier 1.5 assessment, comprising: 1D roughness, 2D roughness, input rainfall and Ynysybwl tunnel blockage.

Table 32 below summarises the calculated freeboard required to provide the 68% and 95% CI for the 1% AEP SoP flood defence wall.

Table 32: Summary of Tier 1.5 freeboard allowances

	Median (m)		**Maximum (m)**		**Minimum (m)**	
Confidence Interval	68%	95%	68%	95%	68%	95%
Freeboard (m)	2.35	5.55	2.55	5.85	1.95	5.00

The variation in parameters has been discussed and agreed with the NRW project team over the duration of the assessment. The model set-up, result extraction and calculation spreadsheet has been reviewed by a Senior Modeller to sense-check the outputs.

The freeboard values output by the assessment are large relative to the required height of the wall. The most impactful parameter is the rainfall that is input to the model, as this directly influences the flows in the channel and therefore levels in the Nant Clydach adjacent to the wall. The uplift value applied to the rainfall is 49% in the 68% CI model run, and 229% in the 95% CI model run. These values are extracted from available hydrological literature regarding uncertainty in design flow and rainfall estimates. These values were deemed appropriate due to the significant uncertainty in the hydrological assessment undertaken for the Ynysybwl catchment. The catchment is ungauged and therefore modelled flows cannot be compared to actual flows in the channel. There is additional uncertainty associated with the impact of the antecedent conditions. Preceding Storm Dennis, there was a prolonged period of rainfall that saturated the catchment. By the time of the Storm Dennis event the catchment was already at capacity which exacerbated the impact of the rainfall that fell. The flows within the Nant Clydach are therefore extremely uncertain as they are influenced by factors which are poorly constrained within a range of potential values.

The shape of the catchment also contributes to the large values of calculated freeboard. As the valley narrows, water becomes trapped within the valley bottom, exacerbated by the addition of the wall, which was modelled as a “glass-wall” in the RUA assessment. The river is confined on the left bank by the steep valley topography and therefore water levels are able to build up within the channel.

The large freeboard values output from the RUA assessment serve to illustrate the difficulty in providing a high-level of confidence in the SoP provided by the wall option, as there are substantial uncertainties in parameters, most significantly in the flows input to the model. Improvements to the understanding of flows in the catchment would require extensive gauging undertaken over years, and it is likely that even with this additional information that substantial uncertainty would remain.

The cost estimates for this option are currently based on a lower value of 750mm freeboard. A nominal 750mm freeboard was agreed in January 2025 and used for the costing and design elements of the project so that the RUA, economic assessment and design elements could be progressed in parallel. A 500mm freeboard allowance was accounted for at SOC stage. A 3 metre high wall provides a confidence far below the 68%ile of 95%ile CI's, as such has a probability of exceedance during the design event (1% AEP) of much greater than 15.9%.

The BCR for a raised defence flood wall with a nominal freeboard of 750mm is <1, and increasing the freeboard will further reduce this.

Wall length

During the RUA assessment, it was noted that when model parameters were varied and levels within the channel were subsequently increased, that overtopping from the channel occurred at new locations. This is partially related to the "glass-wall" method used to represent the defence wall within the RUA model, so as this cannot overtop the water instead outflanks the defence.

In the 68% CI RUA modelling, one of the new overtopping locations is downstream of the existing proposed wall extent, within the car park to the south of the terraced properties on Clydach Terrace. This overtopping location matches anecdotal reports during Storm Dennis that water not only overtopped the wall but also flowed from the south towards the properties on Clydach Terrace.

In the 95% CI RUA modelling, the wall extent is outflanked to the north, adjacent to small huts or sheds on the right bank of the Nant Clydach. This mechanism of flooding has not been observed in reality and is considered likely to primarily relate to the large increases in the various parameters that have been applied to the model.

Therefore, in order to prevent the southern flow path from occurring, the wall would need to be extended downstream to tie in with the Ynysybwl tunnel entrance. The cost estimates for these options are currently based on the shorter wall extent. If the wall were extended to the tunnel inlet, it is likely that the costs for the wall would increase. The BCR for this option is <1, and increasing the wall length is likely to further reduce this. There is also additional uncertainty associated with increasing the wall length downstream as no topographic survey is currently available on the right bank immediately upstream of the culvert inlet.

Residual hazard

The shortlisted options reduce the hazard to properties on Clydach Terrace through different mechanisms and present a markedly different residual flood risk picture, that changes over the appraisal period.

Option 1 – Wall: Residual hazard

An assessment has been made of the residual hazard both in the present day and in the future. The assessment of hazard has been made in accordance with the Defra Flood Hazard Guidance note, FD2320/TR2. A summary of the different hazard categories is provided in Table 33 below. The hazard rating is a function of water depths and velocities and includes an allowance for a debris factor to represent the impact of debris entrained within the floodwaters.

Table 33: DEFRA Flood Hazard Rating FD2320/TR2

Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification
Less than 0.75		Very low hazard – Caution
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm
1.25 to 2.0		Danger for most – includes the general public
More than 2.0		Danger for all – includes the emergency services

Figure 20 below shows the flood hazard in the flood defence option in the present day and future 1% AEP flood event. This assumes that a wall is provided that will not overtop in the present day 1%AEP flood event. The RUA assessment indicates that a minimum freeboard value of 2.2m would be required for the 1% AEP wall with a confidence interval of 68%. This would mean the wall height would be between 3.5 metres and 4.5m. A wall height of 3m has been assumed for costing purposes, however to achieve the reduction in hazard shown within the following figures, a higher wall height would be required.

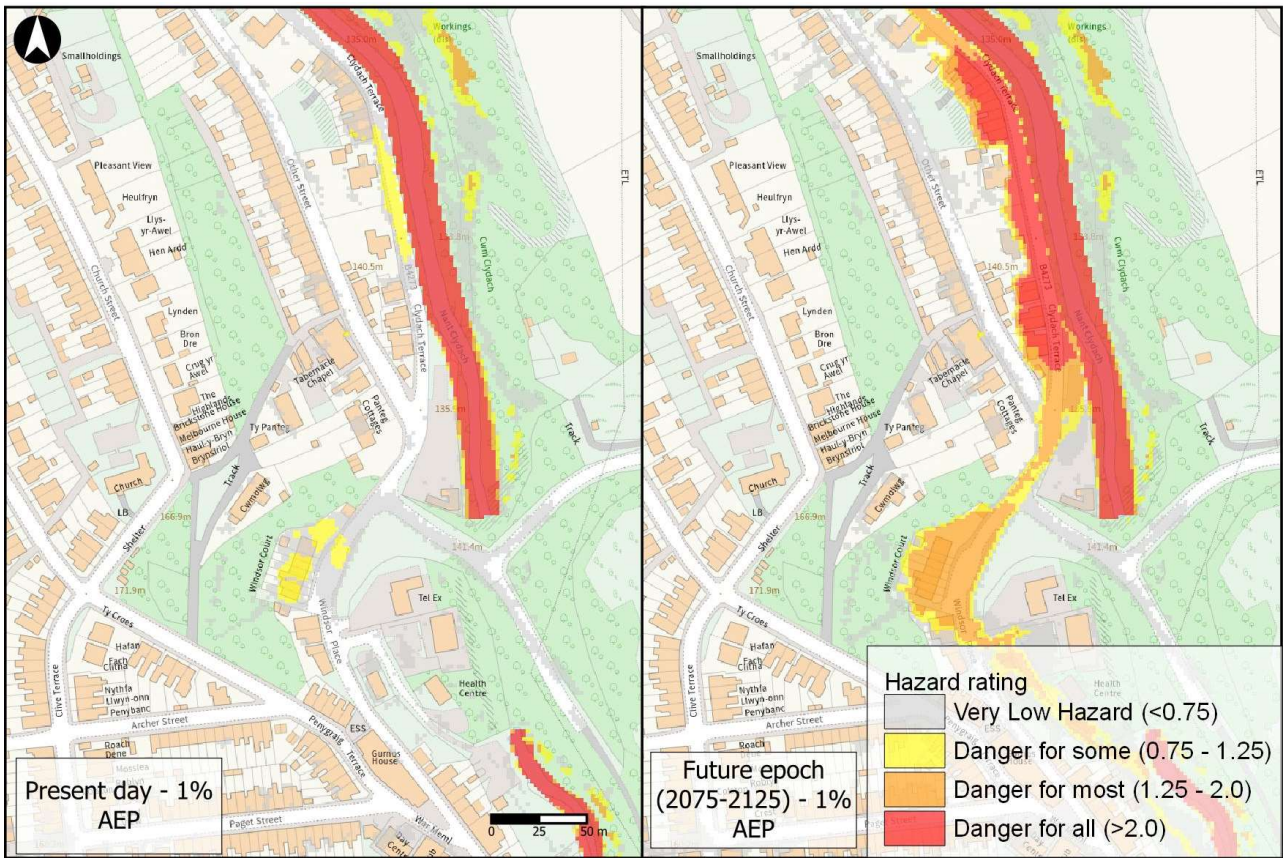


Figure 20: Flood hazard in the present day and future 1% AEP events in the wall option scenario

The raised defence wall option directly removes the risk of fluvial flooding to the community for flood events that do not exceed the SoP provided by the wall. The defence would provide community-level flood hazard reduction in the present day, better protecting both highway users and properties on Clydach Terrace, Windsor Court and Windsor Place.

However flood estimation and modelling is inherently uncertain. A Residual Uncertainty Assessment (RUA) highlighted significant uncertainty with the lack of gauge data in the catchment and the impact of antecedent conditions on the flows within the Nant Clydach. The RUA quantifies the level of uncertainty in the provision of a SoP. Although the modelling shows that for a 1% AEP present day event flood hazard is greatly reduced, there remains the residual risk of overtopping of the raised flood defence wall.

The hazard assessment indicates that, once the SoP of the flood wall is exceeded and the wall is overtopped either due to a flood event occurring with a magnitude that exceeds the SoP of the wall or due to the impacts of climate change, the residual hazard experienced by the properties on Clydach Terrace would pose a danger for all, including the emergency services. The wall option does provide an effective reduction in risk in the present day, however it does not fully remove the risk to the properties in all events or in all epochs, and there remains a substantial residual hazard.

Option 2 – Purchase by Agreement Residual hazard

The Purchase by Agreement option fully removes 16 properties (and their occupiers) most at risk of flooding from the area at risk for all return periods. However the option does not address broader community hazards such as highway users and, increasingly adjacent properties.

Figure 21 below shows the flood hazard in the purchase by agreement option in combination with the WAW assumptions in the present day and future 1% AEP flood event.

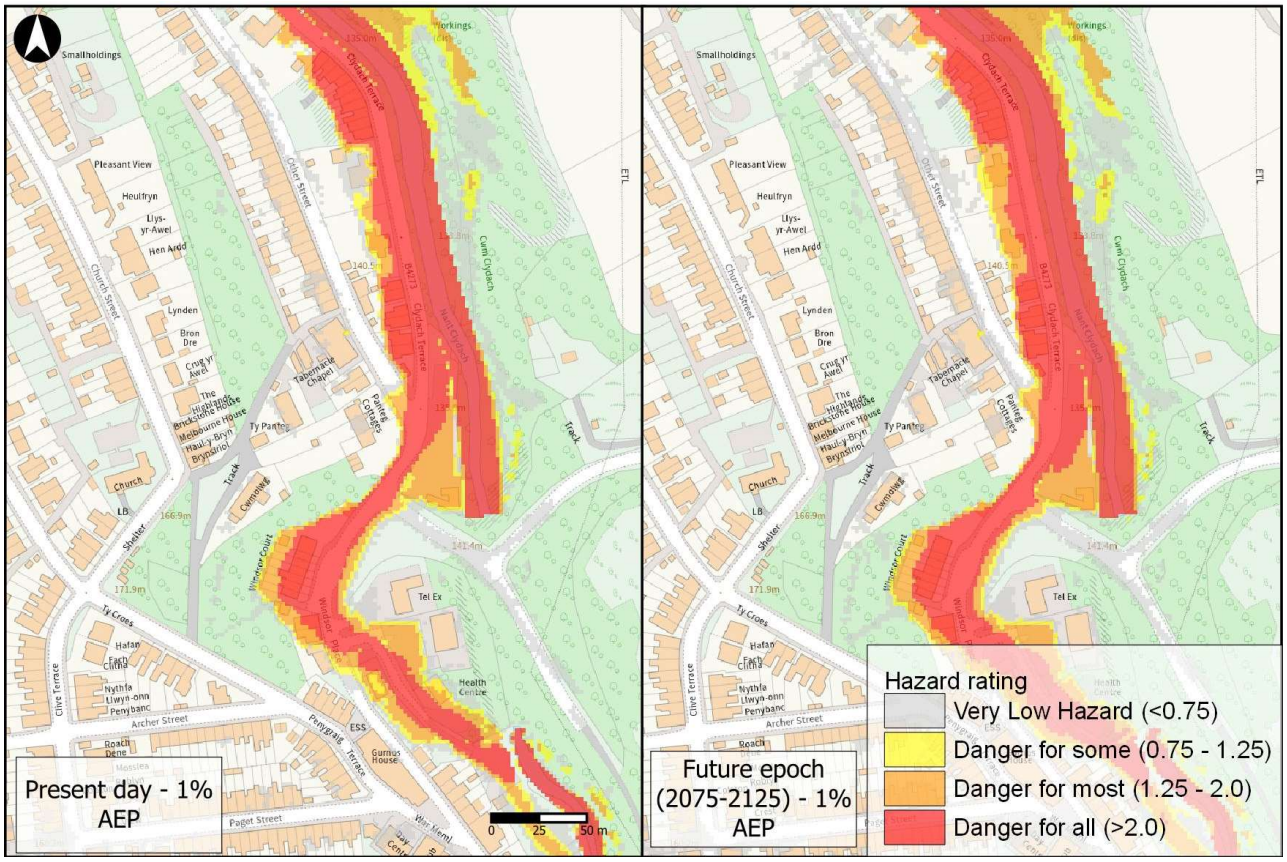


Figure 21: Flood hazard in the present day and future 1% AEP events in the purchase by agreement option in combination with WAW assumptions

In the purchase by agreement option with WAW assumptions, the residual hazard for residents of Windsor Place is shown to be high due to the deep and fast flowing water from the Nant Clydach. This is the same as in the WAW option by itself, as the removal of the properties on Clydach Terrace is shown not to have an impact on flood risk elsewhere.

Figure 22 below shows the flood hazard in the purchase by agreement option in combination with the BAU assumptions in the present day and future 1% AEP flood event.

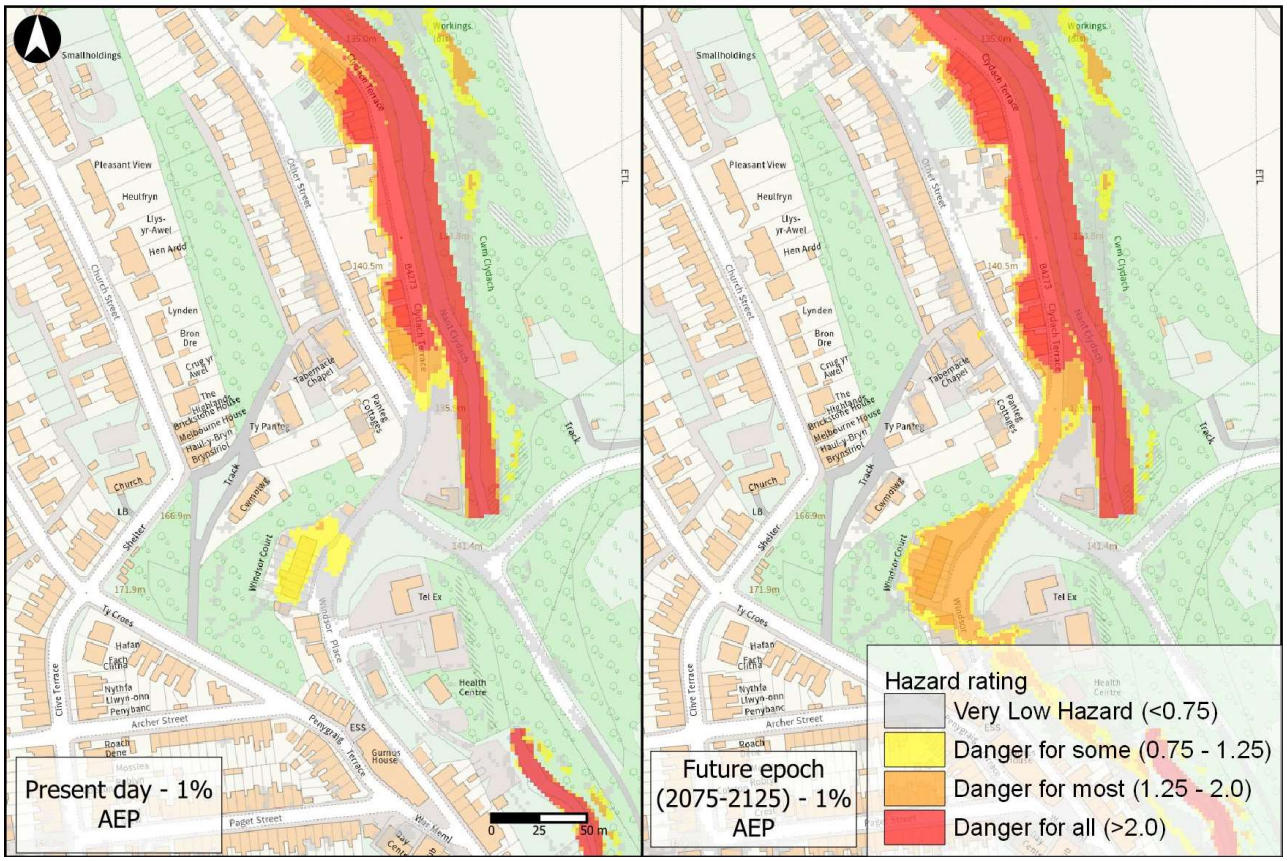


Figure 22: Flood hazard in the present day and future 1% AEP events in the purchase by agreement option in combination with BAU assumptions

In the purchase by agreement option with BAU assumptions, the residual risk to the properties elsewhere in the study area is the same as in the existing BAU scenario. The residual risk in all events increases with the magnitude of the modelled flood event and when the impacts of climate change are taken into account.

Table 34 summarises the number of properties within each risk category for each of the shortlisted options in the present day 1% AEP event. Only properties on Clydach Terrace, Windsor Court and Windsor Place have been considered within the count.

For the hazard assessment, the raw hazard outputs from the model indicated that the three “set back” properties on Clydach Terrace sit within the danger for most or danger for all categories in the BAU, WAW and Option 2 scenarios. However, more detailed assessment indicated that this categorisation was only because a very small proportion of the property footprint sits within the higher hazard category. As the properties are elevated above the highway, and typically only garages and non-residential uses are on the ground floor of the properties and have potential for safe egress to the rear, it has been assumed that the actual hazard experienced by these properties is low. As such, these three properties have been moved into the Very Low hazard category for the BAU and Option 2 BAU scenarios in the present day. For the WAW, one of the properties is within the danger for most category and the other two have been allocated to the Very Low hazard category.

Table 34: Summary of number of properties within each hazard category in the present day 1% AEP event for the shortlisted options

Hazard rating	WAW	BAU	Option 1 - 1% AEP SoP Present Day Wall with PFR *	Option 2 - Purchase by agreement WAW	Option 2 - Purchase by agreement BAU
Very low hazard – Caution	2	4	0	2	4
Danger for some – includes children, the elderly and the infirm	0	7	0	0	7
Danger for most – includes the general public	1	4	0	1	0
Danger for all – includes the emergency services	25	12	0	9	0

* The residual hazard from pluvial flooding shown in Figure 20 would be mitigated with the use of PFR.

Table 35 summarises the number of properties within each risk category for each of the shortlisted options in the future 1% AEP event, at the end of the design life of the scheme.

Table 35: Summary of number of properties within each hazard category in the future epoch (2070-2125) 1% AEP event for the shortlisted options

Hazard rating	WAW	BAU	Option 1 - 1% AEP SoP Present Day Wall with PFR	Option 2 - Purchase by agreement WAW	Option 2 - Purchase by agreement BAU
Very low hazard – Caution	1	3	3	1	3
Danger for some – includes children, the elderly and the infirm	0	0	0	0	0
Danger for most – includes the general public	2	9	9	2	9
Danger for all – includes the emergency services	25	16	16	9	0

The property summary serves to highlight the risk associated with exceedance of the wall SoP, and the risk to properties in the wider study area (including Windsor Place and Windsor Court) if maintenance within the Nant Clydach channel was no longer completed.

Residual flood hazard – impact of climate change

FRM options always come with an inherent risk of exceedance which should be considered, compounded by effects of future climate change. In both cases, the residual hazard increases over time, as climate change drives an increase in flood event size and frequency.

The wall has been designed to protect against the present day 1% AEP event. A comparison has been made of the estimated flows within the channel in future flood events to assess how the SoP is likely to change over the design lifetime of the scheme. In the present day 1% AEP event, the peak flow in the channel is 43.3m^3/s. In the 2% AEP event in the 2070-2125 epoch, where a 25% uplift to rainfall is applied, the peak flow in the channel is 43.8m^3/s. As the future 2% AEP flows exceed the present day 1% AEP flows, by the end of the scheme design life of 100 years that the SoP of the wall option would be less than a 2% AEP event.

In the Purchase by Agreement option there would be fewer properties within the modelled flood extent, however the highway users and the wider community become dependent on the uncertain condition and residual life of the de facto highway wall.

Option 1 – Wall: Detriment assessment

It is likely that any proposed scheme would be subject to planning, and as part of this, an FCA would be needed to consider whether there is any detriment to third parties as a result. A full FCA report has not been undertaken at this stage, as this would be undertaken at FBC stage once the design details of the preferred option are confirmed. A high-level assessment of flood detriment has been undertaken and is presented in the following section.

Figure 23 below shows a depth difference map comparing the model outputs with the wall in place with the BAU results in the present day 1% AEP event. The comparison indicates that the wall option results in a widespread reduction in flood extents and depths. The option does not appear to cause detriment elsewhere, as the water held behind the defence wall is retained within the channel.

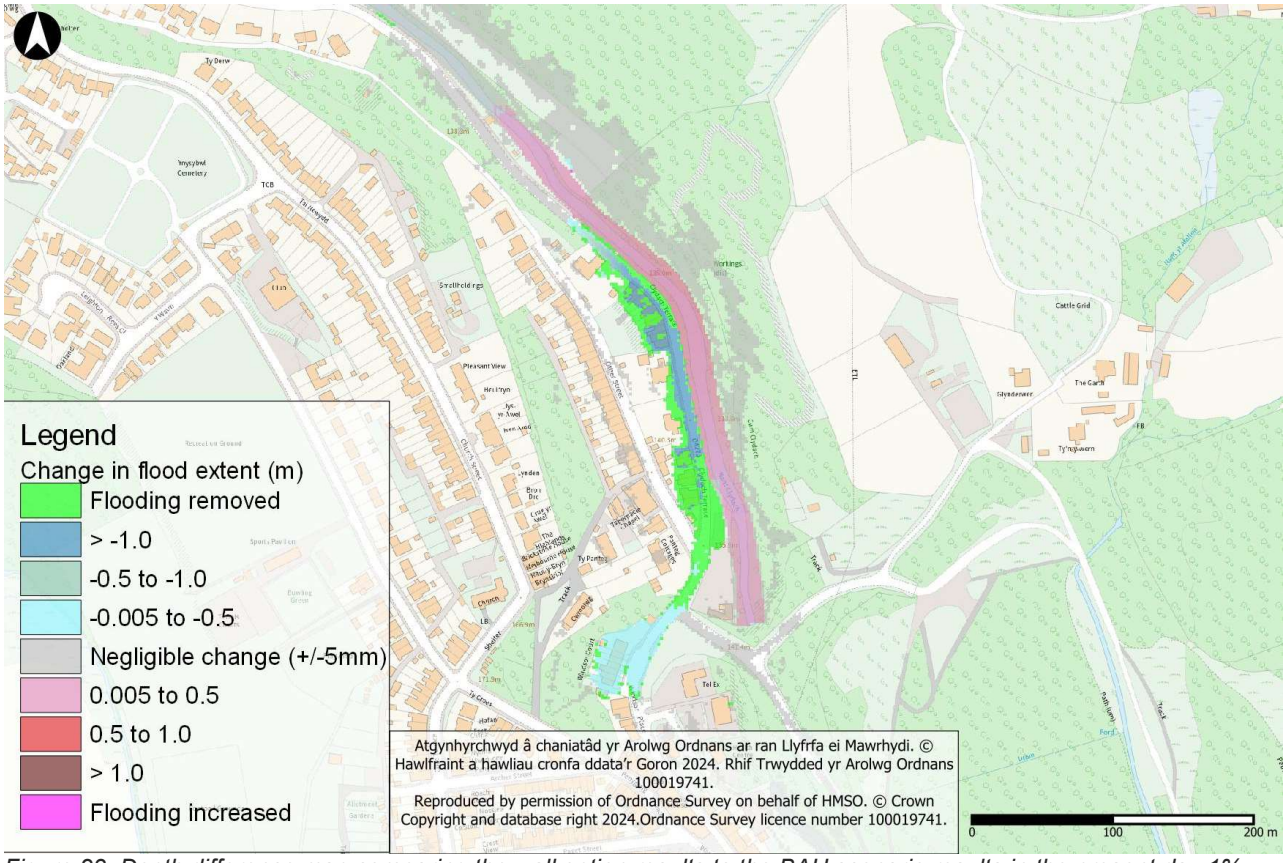


Figure 23: Depth difference map comparing the wall option results to the BAU scenario results in the present day 1% AEP event

Figure 24 shows a depth difference map comparing the model outputs with the wall in place with the BAU results in the present day 0.1% AEP event. The comparison indicates that the wall is outflanked and there is widespread flooding to Clydach Terrace, however the flood depths on Clydach Terrace are not increased relative to the BAU scenario.

There is an increase in flood depths on the left bank of the Nant Clydach, however there are no built receptors in this area and therefore the material increase in risk is low. There is a

small area on the corner of Clydach Terrace and Other Street that experiences an increase in flood depths of 7mm. However, this increase is not shown to impact any properties.

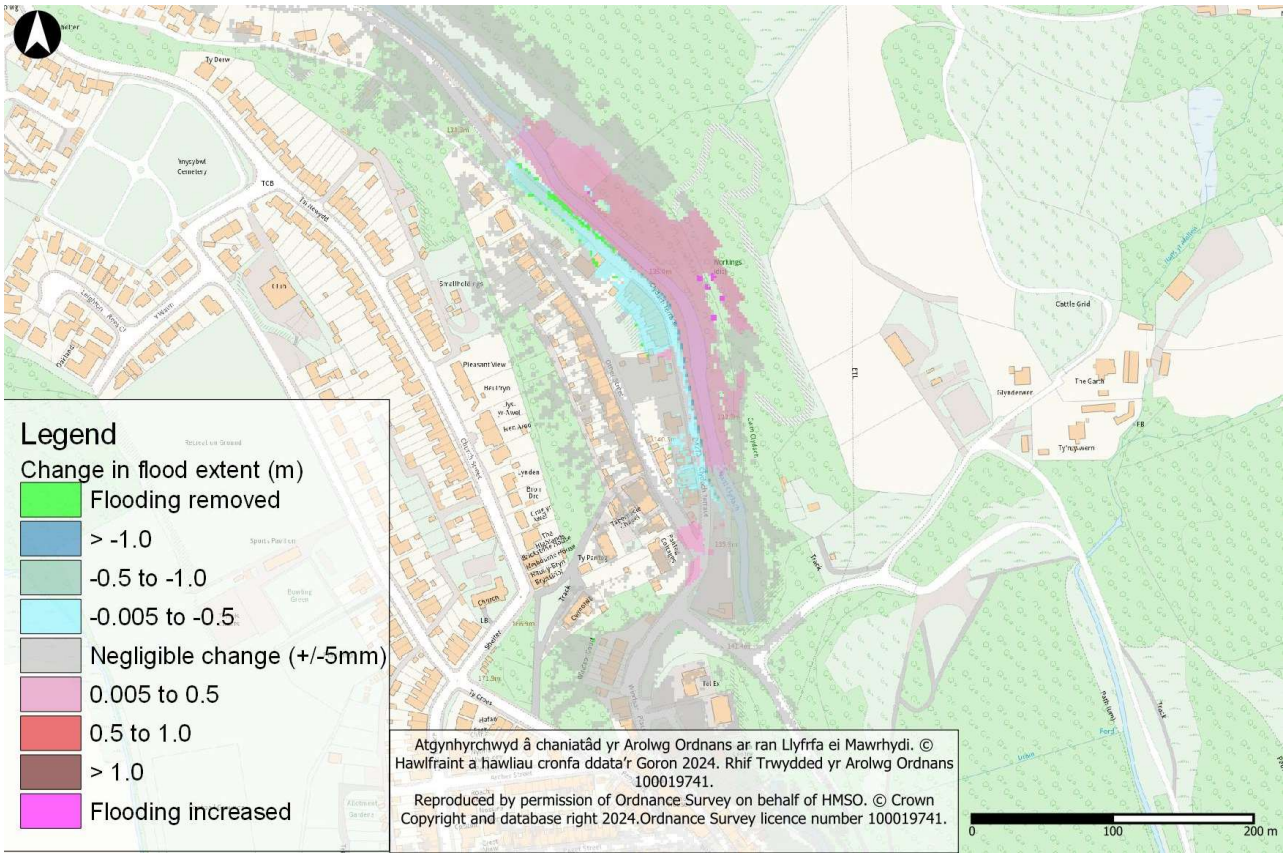


Figure 24: Depth difference map comparing the wall option results to the BAU scenario results in the present day 0.1% AEP event.

The indicative detriment assessment has indicated that the wall option does not result in detriment to third parties.

Option 2 - Purchase by agreement: Legislation and consenting

Within this OBC, NRW is investigating the viability of property purchase among other engineering solutions to reduce flood risk in Ynysybwl. The purchase of property for the management of flood risk is a novel approach and, as such, there is currently no policy or process in place. Accordingly, NRW is unable to provide any further detail on process.

Approval and funding of any FRM option is subject to agreement of WG with any suggested acquisition for Ministers consideration. This would assume that NRW could exercise its compulsory purchase powers (CPO) or at least work within the same principle if agreements with homeowners were reached outside of the CPO process, which would mean that any acquisition would be made in line with the relevant legislation and compensation code. The underlying principle of any acquisition in these circumstances, which is enshrined in the compensation code, is one of 'equivalence'. Through application of this we anticipate that no party affected by acquisition would be better or worse off; this would involve consideration of appropriate market value of properties affected. With consideration to the occupiers of rented properties, NRW is not privy to nor has influence over any contractual arrangement between a landlord and tenant, however the underlying principle remains.

Option 2 - Purchase by Agreement: Ongoing maintenance agreements

The Purchase by Agreement option has been considered in conjunction with either cessation of existing maintenance, or continuation of the existing maintenance. Maintenance that is undertaken by NRW includes removal of silt and shoal in the channel, removal of channel or structure blockages and vegetation clearance.

If all maintenance activities are ceased, as in the WAW scenario, overtopping of the existing highway wall occurs at a much lower AEP than in the BAU scenario, where maintenance is continued. This has implications for the residents of Windsor Place, who are likely to experience an increase in the frequency and severity of flooding from the Nant Clydach. Similarly, the highway that runs adjacent to the Nant Clydach would similarly experience increased fluvial flooding, which has implications for transportation and may also contribute to an increased rate of deterioration of the highway.

As part of the Purchase by Agreement option, an agreement would need to be made as to ongoing maintenance of the channel. It is likely that this agreement would need to be made in discussion with RCTCBC, as the local highways authority. The proposed scheme would also be subject to planning, and as part of this, the FCA would need to consider whether any detriment to third parties arising from the scheme is acceptable. The modelling assessment indicates that the Purchase by Agreement option in itself does not result in detriment elsewhere, as after the demolition of the properties the underlying ground levels would be reinstated as existing. However, the modelling assessment does indicate that the cessation of maintenance results in an increase in flood risk to remaining properties on Clydach Terrace and Windsor Terrace. This option has been assessed in combination with both BAU and WAW assumptions. Any potential increase in flood risk associated with this option would be dependent on the chosen ongoing maintenance regime in the study area.

Recommended Option

The OBC has appraised options shortlisted by the SOC. The appraisal has been based on available information.

In accordance with WG's FRM Business Case Guidance, *the Preferred Option must have a robust economic basis*. The economic appraisal at OBC indicates that the Purchase by Agreement with BAU assumptions and the 1% AEP wall options have relatively similar BCR values, at 0.50 and 0.47 respectively. Assumptions have purposely sought to be optimistic to ensure no potentially viable option is discounted. However sensitivity analysis demonstrated that the whole life costs would need to reduce by more than 50% to provide a marginal FCERM economic case for any do-something option.

Despite a similarly marginal economic case, the options have significant differences.

The raised flood defence wall option likely to increase in impact and cost, to address uncertainties from model parameters and in the absence of a quantified risk allowance. Meanwhile the Purchase by Agreement option is relatively simple from a construction feasibility perspective but a novel approach to FRM and has legal uncertainties.

The shortlisted options reduce the hazard to properties on Clydach Terrace through different mechanisms and present a markedly different residual flood risk picture, that changes over the appraisal period. Whilst the raised defence wall option directly removes the risk of fluvial flooding to properties and highway users in the short term, once it overtops the residual hazard would pose a danger for all. Purchase by Agreement removes 16 properties however highway users and the wider community become dependent on the deteriorating condition and residual life of the de facto highway wall.

The robust FCERM appraisal has found neither do-something option is economically viable and so cannot be recommended to proceed to Full Business Case. This is despite the Business-as-Usual scenario not meeting the project's CSFs.

The findings of this appraisal need to be clearly and meaningfully communicated to all stakeholders. The views on the way forward gathered from all affected members of the community through consultation.

Should collective support of the purchase by agreement concept emerge from stakeholders, then the case for that option could be refined with updated cost estimates to reflect reduced uncertainty. In parallel, joint working with the highways authority will need to explore measures to mitigate risk to users during events through temporary or even permanent road closure.

Meanwhile the ongoing deterioration and maintenance of the highway wall will need to be considered further in conjunction with RCTCBC to somewhat reduce the threat of breach from failure. Remedial works could extend the existing highway wall serviceability. There are also opportunities for upstream natural flood management measures that could somewhat slow and reduce peak flows. Neither address the risk of surface water ponding locally. Beyond current flood doors, measures to houses could increase property flood resilience. But investment justification for any combination of marginal short-term measure has not been investigated explicitly as increasing high flood hazard would remain and the impact continue to be felt by those at risk.

Sources and Assumptions

The following sources of data have been used:

- Flood model outputs from an updated version of the 2022 direct rainfall model produced by Arup;
- National Receptor Database (2024), which contains point features for each receptor in the study area;
- Land Registry House Price Index (2024) – average market value for each type of residential property for the region;
- GDP Deflator information[12] provided by the UK Government; and
- Ordnance Survey (OS) MasterMap (provided by NRW in 2024)

The following assumptions have been made as part of the study:

- In the WAW scenario it is assumed that the highway wall has a residual life of 17.5 years before it reaches condition Grade 5 / failure. In the BAU scenario it is assumed that this is increased to 35 based on the existing maintenance regime. The assessment to inform these residual life estimates was undertaken at the Initial Assessment stage using Environment Agency guidance on asset deterioration and the use of condition grade deterioration curves[13].
- Assumptions have been made within the model for the WAW scenario to represent the cessation of maintenance. To represent this, a blockage has been applied to the Ynysybwl tunnel, siltation has been added to the channel and roughness values in the channel have been increased to represent a lack of vegetation clearance and maintenance. These assumptions have been agreed with NRW and are based on best judgement, the current maintenance regime and known issues that have occurred previously. However, these assumptions are still a simplification of the real-world situation.

The following limitations of the study have been identified:

- The hydraulic modelling was undertaken primarily in 2022, using topographic and channel survey obtained for the purposes of the study. The model was subsequently accepted and reviewed by NRW. The catchment is ungauged. The flood model has been verified comparing predictions against physical evidence of the flooding that occurred during Storm Dennis, including wrack marks. The model was able to broadly reproduce the flood extents observed during this flood event, however modelled levels were slightly lower than observed in the wrack marks. Lack of data to calibrate the model remains the main limitation of the flood modelling study.

[12] https://www.gov.uk/government/collections/gdp-deflators-at-market-prices-and-money-gdp

[13] Environment Agency Guidance - Practical guidance on determining asset deterioration and the use of condition grade deterioration curves: Revision 1. SC060078/R1. https://assets.publishing.service.gov.uk/media/6034c3b7e90e076607c1bf31/_SC060078_Guidance_Report.pdf

- Where PFR is applied to a property, the economic appraisal assumes there is a 75% reduction in damages experienced by the property. Damages are not fully removed to account for the uncertainty in the application and roll-out of PFR, including whether it is deployed in time. This is an assumption and the actual effectiveness of the PFR measures may in reality be much higher or much lower than represented in the economic appraisal.

Post project Financial Consideration

The recommended option is to not proceed to Full Business Case (FBC). On this basis, the project team will proceed to closure. There are no post project financial considerations.

~~Whole life cost of service (if applicable)~~	~~Year 1~~	~~Year 2~~	~~Year 3~~	~~Year 4~~	~~Year 5~~	~~Year 6+~~
-						
-						
-						
~~Total~~						

~~Revenue generation (if applicable)~~	~~Year 1~~	~~Year 2~~	~~Year 3~~	~~Year 4~~	~~Year 5~~	~~Year 6+~~
~~Total~~						

~~Financial Efficiencies (if applicable)~~	~~Year 1~~	~~Year 2~~	~~Year 3~~	~~Year 4~~	~~Year 5~~	~~Year 6+~~
-	-	-	-	-	-	-
-	-	-	-	-	-	-
~~Total~~						

~~Affordability Assessment~~	~~Year 1~~	~~Year 2~~	~~Year 3~~	~~Year 4~~	~~Year 5~~	~~Year 6+~~
~~Whole life costs of Service~~	-	-	-	-	-	-
~~Revenue generation~~	-	-	-	-	-	-

~~Financial efficiencies~~	-	-	-	-	-	-
~~Total~~						
~~Where a negative value is present in the row above please explain how the costs will be afforded?~~						

Milestones

Milestones	Date	Comment
Gateway 0 – Initiation	30/06/2023	Project brief approval and procurement of key supply chain
Gateway 1 – Options Short listing	30/06/2024	SOC
Gateway 2 – Options Selection	16/06/2025	OBC
Gateway 5 – Project Closure	30/09/2025	

Project Start Date *(Original start date)*	**30/06/2023**	**Project Completion Date** *(Forecast)*	**30/09/2025**

Benefits Delivery

Benefits will be investigated, tracked and reported on throughout the project. Benefits are being maximised at optioneering stage including community benefits directly resulting from this project, working with our supply chain partners.

Project Products

Table 36 – Project Products

SOC Product (Links to DMS Area or embedded documents)	**Date produced**
Hydraulic model of study area	Baseline model produced June 2022, further option modelling undertaken in November 2023 and January 2024
Preliminary Ecological Appraisal (PEA)	First issue 17 January 2024

Longlist modelling report	March 2024
Shortlist modelling report	March 2024
Equality Impact Assessment	March 2024
Strategic Environmental Review	March 2024
Economic appraisal	March 2024
Preliminary WFD Assessment	February 2024
OBC Product	**Issue date**
Residual Uncertainty Assessment	22/05/2025
Hydraulic model and outputs	13/02/2025
Hydraulic Modelling Report	23/05/2025
Economic appraisal report	06/06/2025
Baseline Archaeology & Heritage Desk Study	23/01/2025
Natural Flood Management Assessment	16/05/2025
Environmental Scoping Report	23/05/2025
Net Benefit for Biodiversity Appraisal	12/05/2025

Environmental Constraints and Opportunities Plans (Appended to ESR)	23/05/2025
Green Infrastructure Statement Decision Log	23/05/2025
Basis of Design note	05/03/2025
Design drawings	06/03/2025
Tree Clearance Advice Note	10/03/2025
Highway Advice Note	22/01/2025
Carbon Cost Assessment Note	15/05/2025
Wall and embankment screening note	05/06/2025
Designers Risk Assessment	05/06/2025
Appraisal Matrix and Technical Note	05/06/2025
Geotechnical and Geo-environmental desk study	27/01/2025
Asset Operation and Maintenance Schedule	04/03/2025
Clydach Terrace Community Narrative and Ynysybwl Project Report (prepared by the National Flood Forum)	05/06/2025

Glossary

Terminology	Summary Definition
Scenario	A scenario is defined as a representation of what flood risk could be based on an explicit set of assumptions. This can include multiple flood mechanisms. For example, in a Walkaway scenario all risk management authorities would cease their maintenance activities leading to more extensive flooding of communities beyond the status quo. This could be made up of a combination of overtopping of defences, breach, or other flood mechanisms.
Standard of Protection	The maximum annual probability (%) of the extreme water level that, given the various uncertainties, is unlikely to exceed a specific threshold or capability. For example, that of the crest of a wall, the capacity of a flood storage area or the threshold of a property. The SoP changes over time as a result of impacts such as climate change.
Receptor	A receptor is defined as something that is affected by a flood. For example, a residential property in the floodplain would be a receptor.
Appraisal period	The appraisal period is the length of time where damages, benefits, and costs are calculated for a particular intervention.
Present Value	Values expressed in today's terms following relevant discounting.
Cash	Values expressed in today's terms not discounted.
Damages	The value of negative social, economic and environmental impacts caused by flooding.
Benefits	The positive quantifiable and unquantifiable changes that a FRM scheme is expected to produce, i.e. damages avoided
Write off	Write-off is losses to an asset deemed unrecoverable
Flood hazard	A value describing the hazard posed by flooding to people. The value is a function of flood depth and velocity and includes an additional debris factor to account for the risk posed by material entrained within the floodwaters.
AEP	Annual Exceedance Probability (AEP) – The chance of a flood of given size (or larger) occurring in one year. It can be expressed as a

	percentage (such as 1%) or a chance of occurrence (for example, 1 in 100)
BCR	The total value of the benefits (assets protected by the option) divided by the costs.