AECOM

Llanmaes Flood Alleviation Scheme

Flood Consequence Assessment

Vale of Glamorgan Council

Project Number: 60509148

April 2021

Quality information

Prepared by	Checked by	Approved by
Ralph Collard Flood Risk Engineer	Mark Davin Associate Director Richard Moore Senior Consultant	Steve Cook Associate Director Rob Sweet Principal Consultant

Revision History

Revision	Revision date	Details	Authorised	Name	Position
1	16/04/21	Detailed Design update	RS	Rob Sweet	Principal Consultant

Distribution List

# Hard Copies	PDF Required	Association / Company Name
1	Yes	Clive Moon (VoGC), NRW

Prepared for:

Vale of Glamorgan Council

Prepared by:

Ralph Collard
Flood Risk Engineer
T: +44 (0) 117 240 2936
E: Ralph.Collard@aecom.com

AECOM Limited
1 Callaghan Square
Cardiff
CF10 5BT

T +44 (0)29 2067 4600
aecom.com

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1. Executive Summary

Llanmaes village is located approximately 1km north-east of the town of Llantwit Major, Vale of Glamorgan, South Wales. Llanmaes has a history of flood events caused by surface water runoff from the surrounding fields. Once surface runoff reaches Llanmaes, the unnamed watercourse within the village does not have capacity to convey the water resulting in flooding to highways and properties. This report presents the findings of the Flood Consequence Assessment undertaken to confirm the impact of the proposed Llanmaes Flood Alleviation Scheme in accordance with TAN 15.

This study was undertaken by AECOM Limited on behalf of Vale of Glamorgan Council and has been prepared in support of the planning application for the Llanmaes Flood Alleviation Scheme and follows work carried out by Vale of Glamorgan Council since 2004 to find a suitable solution to flooding in Llanmaes.

As part of this study, AECOM developed a Flood Alleviation Scheme through consultation with Natural Resources Wales and Vale of Glamorgan Council, utilising an iterative engineering development process. The Proposed Option is a series of flood mitigation measures that when combined form the Llanmaes Flood Alleviation Scheme and as such, provides a collective effectiveness in reducing flood risk at Llanmaes. The scheme identifies four key areas in Llanmaes where flood mitigation measures are recommended. The Proposed Option utilises flood storage areas up-catchment of Llanmaes, a series of minimally disruptive highways improvements within the village and additional conveyance measures around the north west side of the village. The primary focus, up-catchment of Llanmaes, was to utilise existing agricultural fields to reduce the overall volume of water entering Llanmaes during a storm event.

It is demonstrated within this Flood Consequence Assessment that the Proposed Option provides a significant decrease in maximum flood depths within Llanmaes across all simulated events and that there is no detrimental impact on flood risk downstream of Llanmaes.

Due to the volume of water entering Llanmaes from many discreet locations, intrinsically a key characteristic of a high runoff catchment, it was not possible to completely eliminate flooding within the village. During the 1% AEP + 30% climate change event, the Proposed Option produces a reduction of properties affected by flooding from 61 to 26, i.e. 35 properties are completely removed from inundation in comparison to the Baseline scenario. For those 26 properties which remain at risk of flooding, the level of risk is reduced compared to the current situation and may be managed through the implementation of targeted Property Level Resilience measures.

A key risk to the successful implementation of the Llanmaes Flood Alleviation Scheme is in acquiring land permission to create the upstream storage locations and formalise the outfalls of the three proposed ditches. Discussions are ongoing with local landowners but without introduction of upstream storage measures, the scheme will not be effective. AECOM has worked with Vale of Glamorgan Council and the affected landowners in preparing the design.

2. Introduction

2.1 Commission

This report presents the findings of a Flood Consequence Assessment (FCA) undertaken to confirm the impact of the proposed Llanmaes Flood Alleviation Scheme (FAS). This study was undertaken by AECOM Limited on behalf of Vale of Glamorgan Council and has been prepared in support of the planning application for the Llanmaes FAS, Llanmaes, Wales.

2.2 Background

The village of Llanmaes is situated on the eastern bank of Llanmaes Brook, approximately 1km north-east of Llantwit Major, Vale of Glamorgan, South Wales (Figure 2-1). A small, heavily modified unnamed watercourse, forming a tributary of Llanmaes Brook, flows from north-east to south-west through Llanmaes and provides the primary conveyance route for the residential area and surrounding agricultural land.

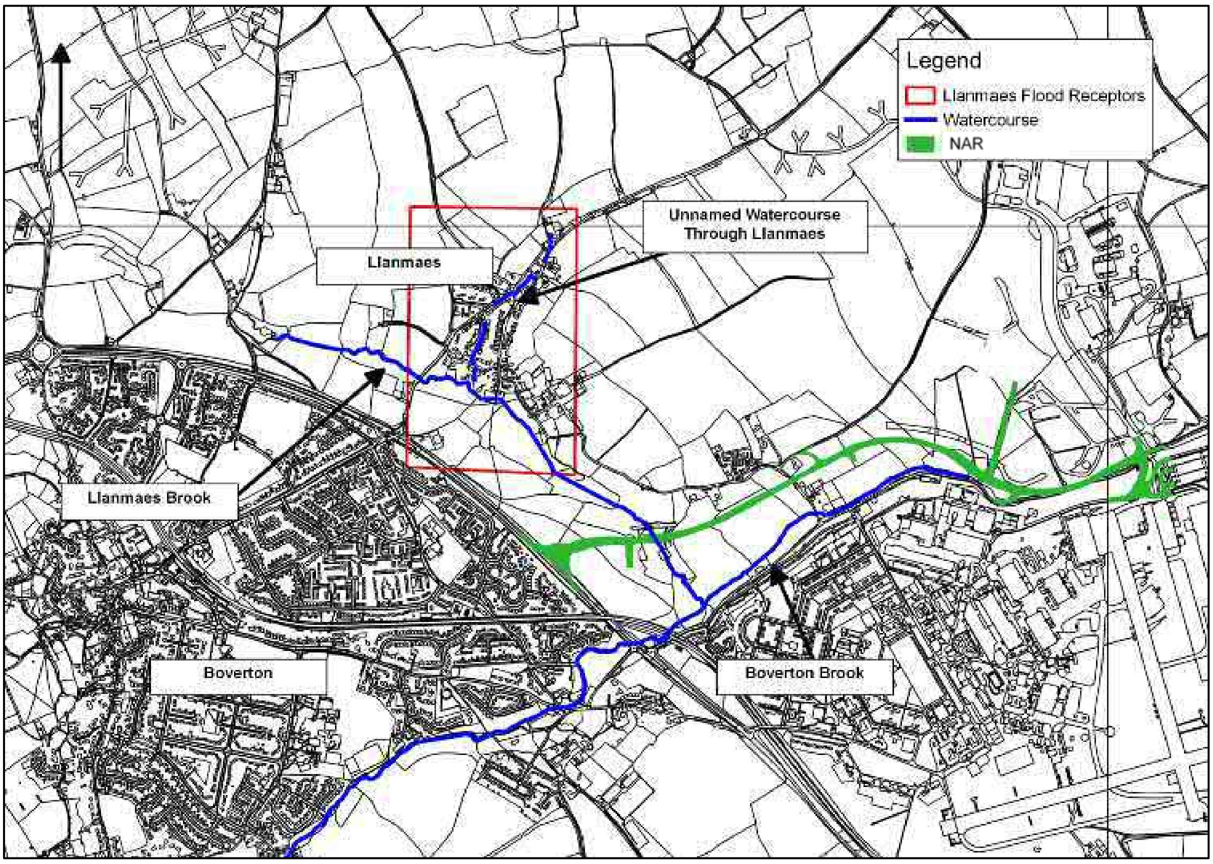

Figure 2-1: Overview Map

Llanmaes has a history of flood events caused by surface water runoff from the surrounding fields. Once surface runoff reaches Llanmaes, the unnamed watercourse does not have capacity to convey the water away resulting in flooding to highways and properties.

Since 2004, Vale of Glamorgan Council (VoGC) has explored a number of options for the Llanmaes FAS through the production of a Pre-feasibility Study[1], Project Appraisal Report[2] (PAR) and Options Appraisal Report[3] (OAR). The aim of the process between the three studies was to develop a feasible and technically suitable option to take forward for construction which reduces flood risk to properties in Llanmaes, whilst providing no detriment with respect to flooding downstream in Boverton via Boverton Brook.

[1] Vale of Glamorgan (2004) Pre-Feasibility Study – Llanmaes
[2] Vale of Galmorgan Council (2009) Project Appraisal Report – Llanmaes Flood Alleviation Scheme
[3] Vale of Galmorgan Council (2014) Option Appraisal report – Llanmaes Flood Management Scheme

Since production of the OAR, a potential preferred solution was identified but had not been proven through appraising positive and negative impacts using a hydraulic model or subsequent presentation within an FCA.

In order to progress the work completed during 2004-2014 by VoGC, AECOM was appointed by the Welsh Government in May 2017 and subsequently by VoGC to appraise the solution determined in 2014 by the OAR, taking forward the most appropriate elements of this scheme and to develop a Proposed Option for the Llanmaes FAS. A Proposed Option has been developed through consultation with Natural Resources Wales (NRW), VoGC and local landowners.

2.3 Aims and Objectives

This FCA has been undertaken in accordance with Technical Advice Note 15 (TAN 15): Development and Flood Risk[4] which supplements the policy set out in Planning Policy Wales[5] (PPW). According to TAN 15, planning applications for development proposals in Development Advice Map Zone A[6] do not require an FCA however any new development must demonstrate that there is 'no increase in flooding elsewhere' (Section 4.1). Therefore, an FCA has been produced to assess the flood risk impacts in Llanmaes and assess any impacts downstream of the scheme. This FCA should be read in conjunction with the associated hydraulic modelling report in Appendix C,

In order to complete the FCA, the following was undertaken:

- Collect and review available flood risk data including NRW information and previous reports including the 2017 St Athan Northern Access Road (NAR) FCA[7] and 2017 VoGC Preliminary Flood Risk Assessment[8] (PFRA);
- Update and extend the existing hydraulic model for the NAR from the previous 2017 FCA completed by AECOM, to include the village of Llanmaes and the proposed FAS;
- Assess the flood risk to and from the proposed Llanmaes FAS;
- Summarise the information obtained to confirm that the proposed FAS appears suitable to counteract the existing flooding in Llanmaes and not cause any detrimental effects downstream to the proposed NAR and to Boverton; and,
- Produce an FCA report in full accordance with TAN 15 to accompany the planning application.

2.4 Consultation and Site Visits

AECOM has consulted with VoGC and NRW throughout this study to build a robust assessment of flood risk to and from the proposed Llanmaes FAS. Table 2-1 shows the consultations and site visits that have been undertaken as part of this study.

Meeting minutes detailing the proposed hydraulic modelling methodology were produced by AECOM in July 2017[9] and confirmed by NRW as being acceptable to appropriately determine the flood risk to and from the Llanmaes FAS. The memo outlines that fluvial and pluvial hydraulic models would be used to investigate the flood risk at the site to allow for results comparable to those within the NAR FCA (AECOM 2017) as this scheme is intrinsically linked to the upper catchment in Llanmaes via Llanmaes Brook (Figure 2-1). Throughout this study it was determined that using more conventional fluvial based 'point inflow' hydraulic modelling through Llanmaes village would not be representative of the real issues posed to the location and could therefore produce an unreliable estimation of flooding and resultant scheme design taken forward. Therefore, under agreement with NRW (20/02/18), only pluvial modelling of the unnamed tributary catchment through Llanmaes has been assessed due to evident overland flow flood mechanisms across the adjacent fields.

[4] Technical Advice Note (TAN) 15, NRW. Available online at: https://gov.wales/technical-advice-note-tan-15-development-and-flood-risk. Last accessed: 13/04/21
[5] Planning Policy Wales. Available online at: https://gov.wales/topics/planning/policy/ppw/?lang=en. Last accessed: 14/04/21.
[6] Development Advice Map, NRW. Available online at: https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=2. Last accessed: 14/04/21
[7] AECOM (2017) – St Athan Northern Access Road Flood Consequence Assessment
[8] Preliminary Flood Risk Assessment (PFRA) Vale of Glamorgan Council. Available online at: http://www.valeofglamorgan.gov.uk/Documents/Living/Highways%20&%20infrastructure/Exec-Summary-ENG.pdf.
[9] AECOM (July 2017) Llanmaes FAS – NRW revised Minutes 170707

Following a meeting with NRW in July 2017 it was agreed that AECOM would adopt a revised Baseline hydraulic model representation under the assumption that the construction of the NAR and all associated flood mitigation measures has taken place. The construction of the NAR and associated flood mitigation measures was completed in March 2019 in accordance with its design and therefore the representation in the hydraulic model is consistent with the present-day conditions.

A site visit was undertaken in June 2017 at the outset of the project to inform the Baseline hydraulic modelling of the unnamed watercourse through Llanmaes and the surrounding land. During the site visit, flood mitigation measures, including those proposed in the OAR (2014), were identified for inclusion in the Llanmaes FAS to be taken forward in the hydraulic modelling. Once the Baseline and Proposed Option modelling had been developed, a second site visit was undertaken November 2017 by AECOM and VoGC to ground truth the proposed flood mitigation measures. Further site visits have been undertaken by the design team through 2018 to 2021 to improve the constructability of the scheme.

Table 2-1: FCA Consultation and Site Visits

Consultation/Site Visit	Date	Comment
NRW/VoGC/AECOM	07/07/2017	Project Start Up meeting and agreement of methodology
AECOM	01/06/2017	Hydraulic modelling data gathering
VoGC/AECOM	10/10/2017	OAR option review and modelling update
AECOM/VoGC	17/11/2017	Ground truthing of AECOM Proposed Option with VoGC
NRW/AECOM	20/02/2018	Pre-Model handover meeting
NRW	27/03/2018, 19/10/18, 08/01/2019	Review of Hydraulic Model and Hydraulic Modelling Report (Stage 5, Section 7.1)
NRW	08/07/2019	Detailed design agreement to submit detailed design option to planning
VoGC	08/11/2019	Detailed design option submitted to VoGC for review
AECOM/VoGC	10/09/2020	Site visit and trial pits investigation works. Discussed constructability
AECOM	17/02/2021	Design team site visit, confirm drainage on West Road and Gadlys Lane
AECOM/VoGC/Land Agent	22/02/2021	Site visit to discuss landownership and constructability of the scheme

AECOM submitted the Baseline and Proposed Option design (Stage 5, Section 7.1) to NRW in January 2019 for review and comment as a key stakeholder in the scheme. AECOM subsequently improved the Baseline and Proposed Option hydraulic models to address NRW's comments and create a technically robust representation of flood risk within the Llanmaes Brook catchment. At Stage 5 NRW agreed in principle that the presented Proposed Option does not cause any detrimental effects downstream to Boverton.

3. Site Description

3.1 Existing Site

Llanmaes village is located approximately 1km north-east of the town of Llantwit Major, Vale of Galmorgan, South Wales. Figure 3-1 shows an overview of the study area within the Llanmaes Brook catchment and the proximity to Boverton Brook and the St. Athan NAR.

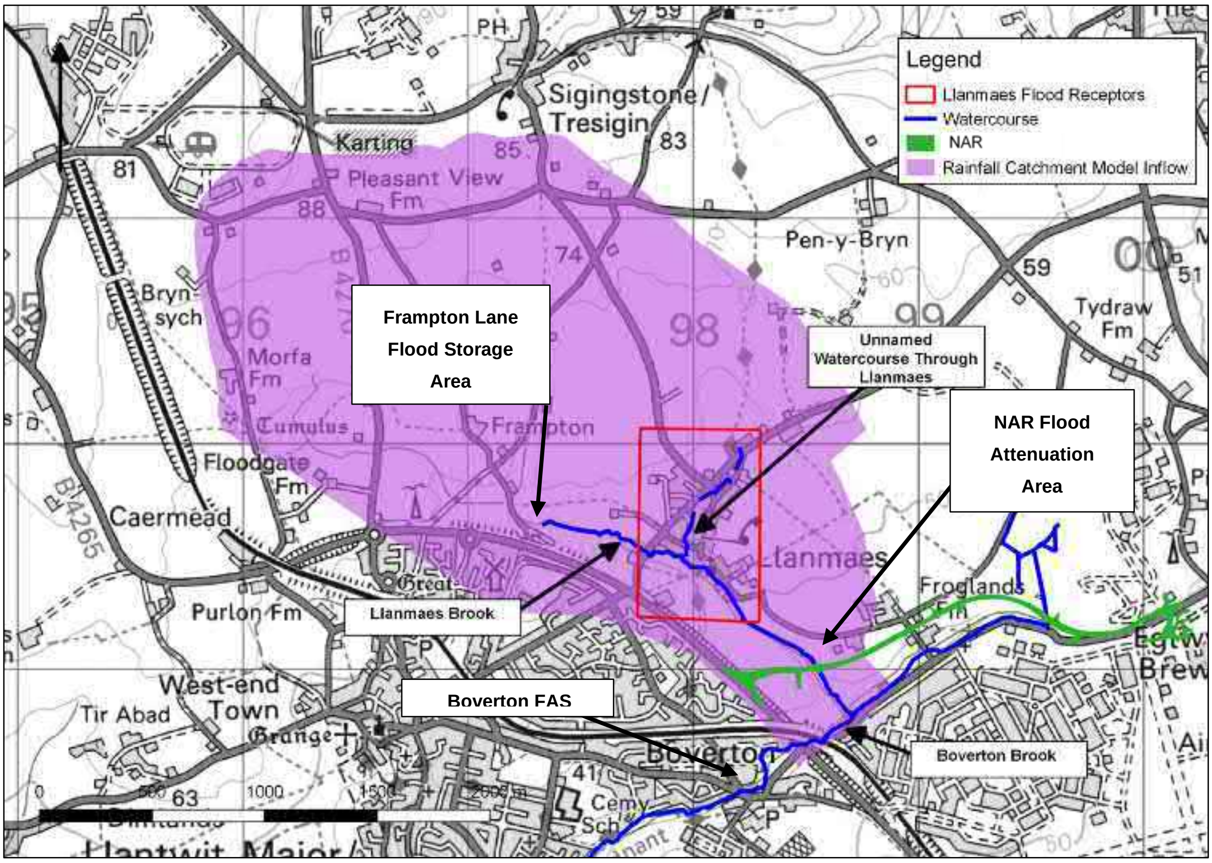

Figure 3-1: Llanmaes Site Overview

Llanmaes is predominately a residential village surrounded by agricultural fields to the north and east. The village is bounded by Llanmaes Brook to the south west and is intersected by a heavily modified unnamed tributary of Llanmaes Brook that flows through the village (Section 3.2). A Village Green at the north east of Llanmaes is bounded on two sides by West Road and Gadlys Lane (Figure 3-2) and forms a focal point for highways in the village. Sigingstone Lane rises steeply to the north west from the junction at the Village Green. Elevations fall from West Road and Gadlys Lane on to Low Road where the unnamed tributary passes beneath the highway and towards Tara House and ultimately into Llanmaes Brook.

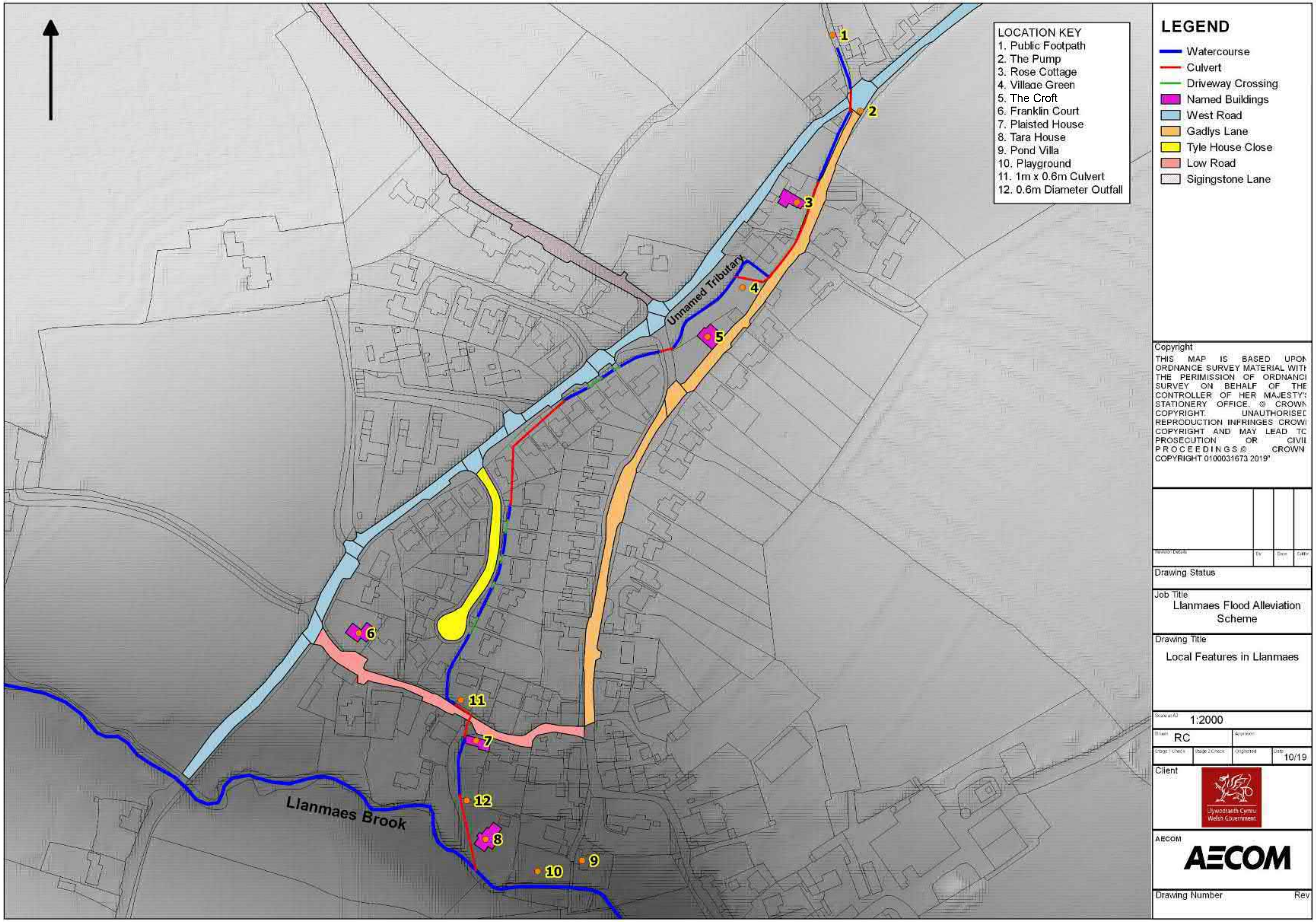

Figure 3-2: Local Features in Llanmaes

3.2 Local Water Features

Figure 3-1 displays the local water features that require consideration in this FCA.

- Unnamed Tributary through Llanmaes – The ordinary watercourse is ephemeral in the upper reaches of the catchment and a public footpath that enters the village from the north east forms the channel bed in flood events. The watercourse passes beneath West Road near the Pump and flows through a small open stone lined channel along Gadlys Lane before entering a culvert near Rose Cottage. The watercourse outfalls into the Village Green where a larger open grassed channel conveys water to the south west. Once the watercourse passes beneath West Road it flows through residential gardens in a small stone lined channel and passes in and out of culvert beneath driveways and residential gardens along Tyle House Close. The watercourse flows beneath Low Road though a 1m x 0.6m culvert before outfalling west of Plaisted House and along the driveway of Tara House.
- The Unnamed Tributary enters a 600mm diameter pipe before ultimately outfalling into Llanmaes Brook upstream of Tara House.
- Llanmaes Brook – Designated as Main River and flows north west to south east from Frampton (NGR 297261, 170022) to the confluence with Boverton Brook (NGR 298715, 168770). The Llanmaes Brook catchment is approximately 5.2km^2 with a maximum elevation of approximately 85m AOD. The Brook bounds the west end of Llanmaes and passes beneath a series of bridges and the NAR before out falling into Boverton Brook. The catchment is intersected by the railway line and B4265 in the lower west catchment area.
- Boverton Brook – A tributary of the River Hoddnant where the confluence is downstream of Boverton. The watercourse is designated as Main River from St Athan (NGR 169181, 299582) to Boverton Rd and passes beneath the railway and B4265 before reaching Boverton.

3.2.1 Flood Defence Structures

There are no flood defence structures located within Llanmaes, however there are three flood defence structures located within the vicinity of Llanmaes (Figure 3-1) which are

- The Frampton Lane Flood Storage is located in the upper Llanmaes Brook catchment near the village of Frampton (NGR 297354, 169647). The outfall is regulated from the flood storage area by a flapped culvert that allows water to back up and flood the storage area in times of high flows.
- NAR Attenuation Area was constructed in March 2019 and is located in the mid Llanmaes Brook catchment downstream of Llanmaes. The storage area was constructed as part of the St Athan NAR scheme.
- Boverton FAS was constructed in 2018 by VoGC and is located on Boverton Brook within the town of Boverton. The scheme consists of the renewal of an existing culvert in Boverton and replacement with a new 4m wide culvert constructed in its place with the alignment straightened to better deal with flood water.

3.3 Geology and Hydrogeology

The British Geological Society[10] map data show that the Llanmaes site is underlain by Porthkerry Member Limestone and Mudstone Formation and were formed approximately 190 – 200 million years ago in the Jurassic period. This geology is overlain with alluvium around the Llanmaes Brook and Boverton Brook river valleys.

VoGC have undertaken trial pitting in the village that indicate that bedrock is relatively close to the surface. Following the development of the Proposed Option a detailed ground investigation of 24 trial pits was undertaken in September 2020[11] within the fields to the north of Llanmaes to determine the suitable depth of proposed ditches and suitability of use of material in the proposed bunds. The ground investigation report is found within Appendix A and the ground conditions encountered are summarised in Table 3-1.

[10] British Geological Society – Geology of Britain Viewer. http://mapapps.bgs.ac.uk/geologyofbritain/home.html. Accessed 13/04/21

[11] AECOM, 2020. Llanmaes Village Flood Bund Technical Note

Table 3-1: Summary of Geology in Llanmaes

Stratum	Description	Depth from (m)	Depth to (m)
Topsoil	Dark brown clayey topsoil	0	0.25
Weathered Blue Lias (subsoil)	Brown slightly gravelly slightly sandy clay	0.15	1.55
Porthkerry Member (Blue Lias)	Limestone with clay	0.55	1.85

Source: AECOM, 2020.Site Investigations, Llanmaes Village Flood Bund Technical Note

A detailed Ground Investigation (GI) was carried out as part of the NAR scheme, located downstream of Llanmaes, and is outlined in detail within the St Athan NAR FCA[12]. A series of trial pits and boreholes were undertaken between November 2016 and January 2017 as part of the GI. Table 3-2 shows the expected geology within the vicinity of Llanmaes. The strata thicknesses are based on data from the four rotary boreholes and groundwater was discovered at 0.7 – 1.3m below ground level (bgl).

Table 3-2: Summary of Geology in the Wider Catchment

Stratum	Depth To Stratum	Geological Map Description/ Anticipated Presence	Thickness (m)
Made Ground	Ground Level	Soft slightly gravelly silty Clay.	0.20-0.65
Probable Alluvium	0.2-0.45	Silty/ gravelly/ sandy Clay. Appears to be only present in proximity to the watercourses in the area	0.10-2.20
Distinctly Weathered Porthkerry Member	0.35-1.30	Interbedded limestone with clay bands	0.01-1.7*
Partially Weathered Porthkerry Member	0.70-2.40	Interbedded limestone with clay bands	0.10*-7.80
Porthkerry Member	2.40	Interbedded limestone with clay bands	5.60*

**Base of Stratum not proven, greater thickness may be present.*

Source: AECOM, 2017. St Athan Northern Access Road, Factual Ground Investigation Report. Hydrogeology

The site is not in a Groundwater Source Protection Zone (SPZ) as designated by NRW to limit potential pollution activities, nor are there any sites located within 1km radius of the site.

The Geo Environment Report[13] produced for the NAR Scheme indicates that it is likely Llanmaes is located within a Secondary A Aquifer area. The Porthkerry Limestone soil forms a permeable layer which is capable of supporting water supplies at a local rather than a strategic scale, and in some cases forming an important source of base flow to rivers. Therefore, it is unlikely there will be any significant restrictions on surface water runoff to ground.

3.4 Topography

Llanmaes is located within a shallow valley that falls from north east to south west towards Llanmaes Brook (Figure 3-3). The catchment rises to a maximum elevation of 90m AOD to the north of the village and 58m AOD to the east of the village. The ground elevations fall from approximately 60m AOD at the north end of the village to 45m AOD at Llanmaes Brook. The shallow valley broadly follows Gadlys Lane, West Road and Tyle House Close before intersecting Low Road near Plaisted House towards Llanmaes Brook. Agricultural fields and highways form overland flow routes for surface water to pass into the village. A public footpath to the north of the village forms the bed of the primary flow route to the unnamed tributary before it enters the village. This footpath is located within a cutting between agricultural fields, which accumulates field runoff during heavy rainfall events.

[12] AECOM 2017. St Athan Northern Access Road, Factual Ground Investigation Report. Hydrogeology
[13] AECOM, 2016. St Athan Northern Access Road Phase 1 Geo-Environmental Assessment.

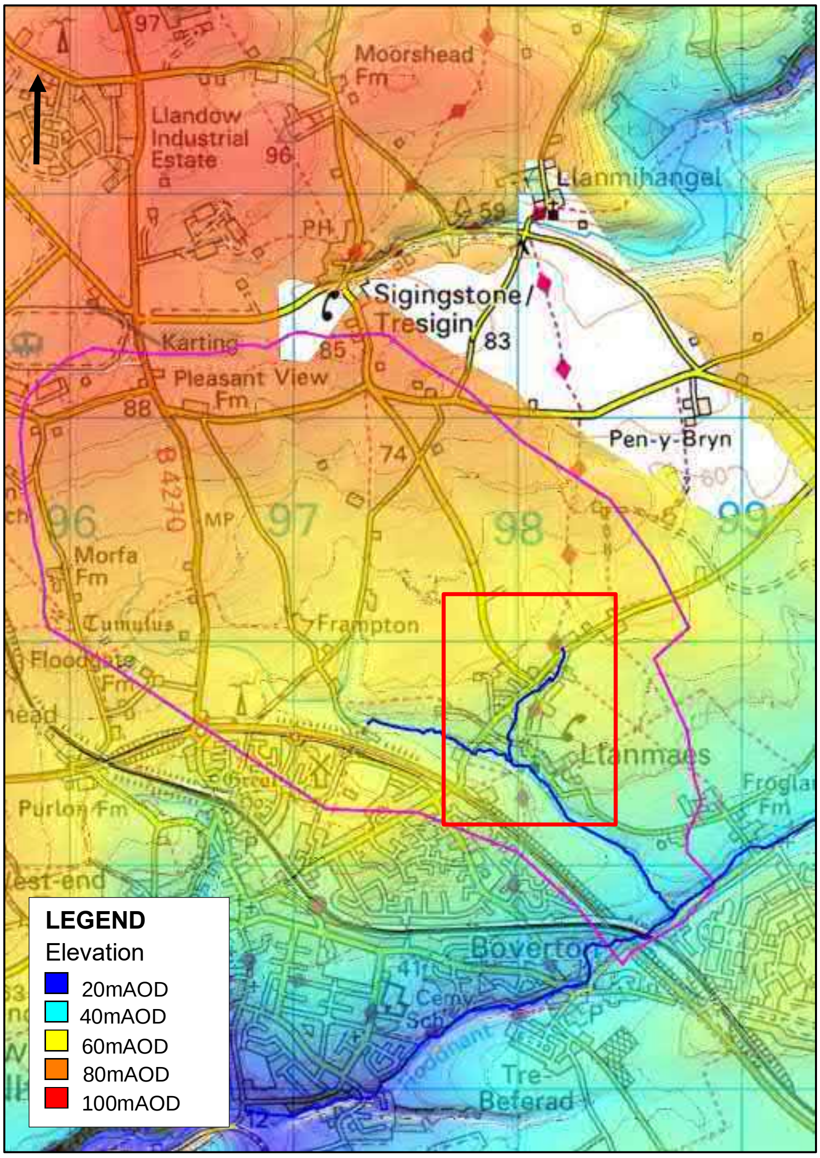

Figure 3-3: Llanmaes Brook Catchment Topography

3.5 Historic Flooding

Discussions with VoGC and previous project reports have shown that Llanmaes has a long history of flooding. Under storm conditions, the watercourse through the village does not have capacity to convey water away from the village and this, combined with potential blockages of the watercourse, exacerbate flooding in Llanmaes. It is understood from the 2009 PAR (VoGC, 2009) that Llanmaes has suffered property flooding approximately every five years. Examples of recent flood events include: October 1998, November 2007, December 2012, November 2016 and January 2018, November 2019, October 2020, and December 2020. As a consequence of historic flooding in Llanmaes 9 properties have been installed with some form of Property Level Protection (PLP). It is noted that this has not been considered in the hydraulic modelling outputs within this report as installation of PLP was implemented during the development of the proposed option hydraulic model.

3.6 Proposed Development

The AECOM Proposed Option identifies four key areas in Llanmaes where flood mitigation measures are recommended. Through the modelling process it became apparent that the most effective way to reduce flooding within Llanmaes was to intercept overland flow as close to the source as possible, upstream of the village, rather than trying to control it once it has entered the village where there is little space to introduce effective measures.

For this reason, the Proposed Option utilises flood storage areas within agricultural fields to the north and up-catchment of Llanmaes in conjunction with a series of minimally disruptive highways improvements within the village and additional conveyance measures to the north of Llanmaes. Figure 3-4 shows the location of the proposed flood mitigation measures, a description of the key element of the scheme are summarised in Table 3-3 and fully outlined within Appendix B:

Table 3-3: Description of Proposed Development

Area (Ref: Figure 3-4)	Flood Mitigation Measures	Purpose
1	Four upstream flood storage areas with 300mm outlet pipes. The specification of outlet design can be found in the supporting planning application. Bund 1 outfalls into Ditch 2 cut off ditch. Each FSA has a 300mm flood relief pipe 1.3m above the primary outlet invert in case of blockage.	Reduce overall volume of water reaching Llanmaes during a flood event
2	(A) Road re-profiling along West Road to the Village Green (B) Associated low level kerb raising along southern roadside on West Road (C) Road re-profiling and raised road table/junction across Gadlys Lane and West Road junction	(A, B & C) Maintain overland flow from Gadlys Lane and any out of bank flow within West Road
	(D) Re-profiling of the Village Green and re-profiling of Gadlys Lane, north of The Croft. Two swales connecting West Road and Gadlys Lane to the Village Green watercourse.	(D) Improve capacity of the channel at the Village Green and direct any overland flow from Gadlys Lane and West Road towards the unnamed tributary
3	(A) Road re-profiling along West Road from Tyle House Close to Franklin Court (B) Associated low level kerb raising and footway re-profiling along southern roadside on West Road	(A and B) Maintain overland flow within West Road and conveyed to Llanmaes Brook to the south west
	(C) Road re-profiling and raised road table/junction at the entrance to Tyle House Close	(C) Restrict overland flow passing down through Tyle House Close
	(D) Road re-profiling and raised road table/junction at Low Road and West road junction.	(D) Restrict overland flow passing from West Road into Low Road
	(E) Upgrading and installing new drainage system on West Road downstream Village Green until south end of scheme	(E) Increase drainage capacity. Benefit to overall flood water capacity is not considered under this model
4	(A) Cut off ditch along field boundary from Bund 1 outfall to Llanmaes Brook including check dams for storage. Maintains a series of agricultural crossings for access to fields	(A) Reduce volume of water entering Llanmaes onto West Road
	(B) Low level bunding along southern edge of Ditch 1 and Ditch 2	(B) Prevent out of bank flow from cut-off ditch passing to the south
	(C) Ditch 3 taking highway drainage to the north of West Road and outfalling into Llanmaes Brook	(C) Ensure the FAS scheme outfalls into the fields to the north of West Road
	(D) Filter drain collects water from Sigingstone Lane and diverts into Ditch 1	(D) Reduce the volume of water entering Llanmaes from Sigingstone Lane. It is noted that this is simplified within the hydraulic model (Appendix C)

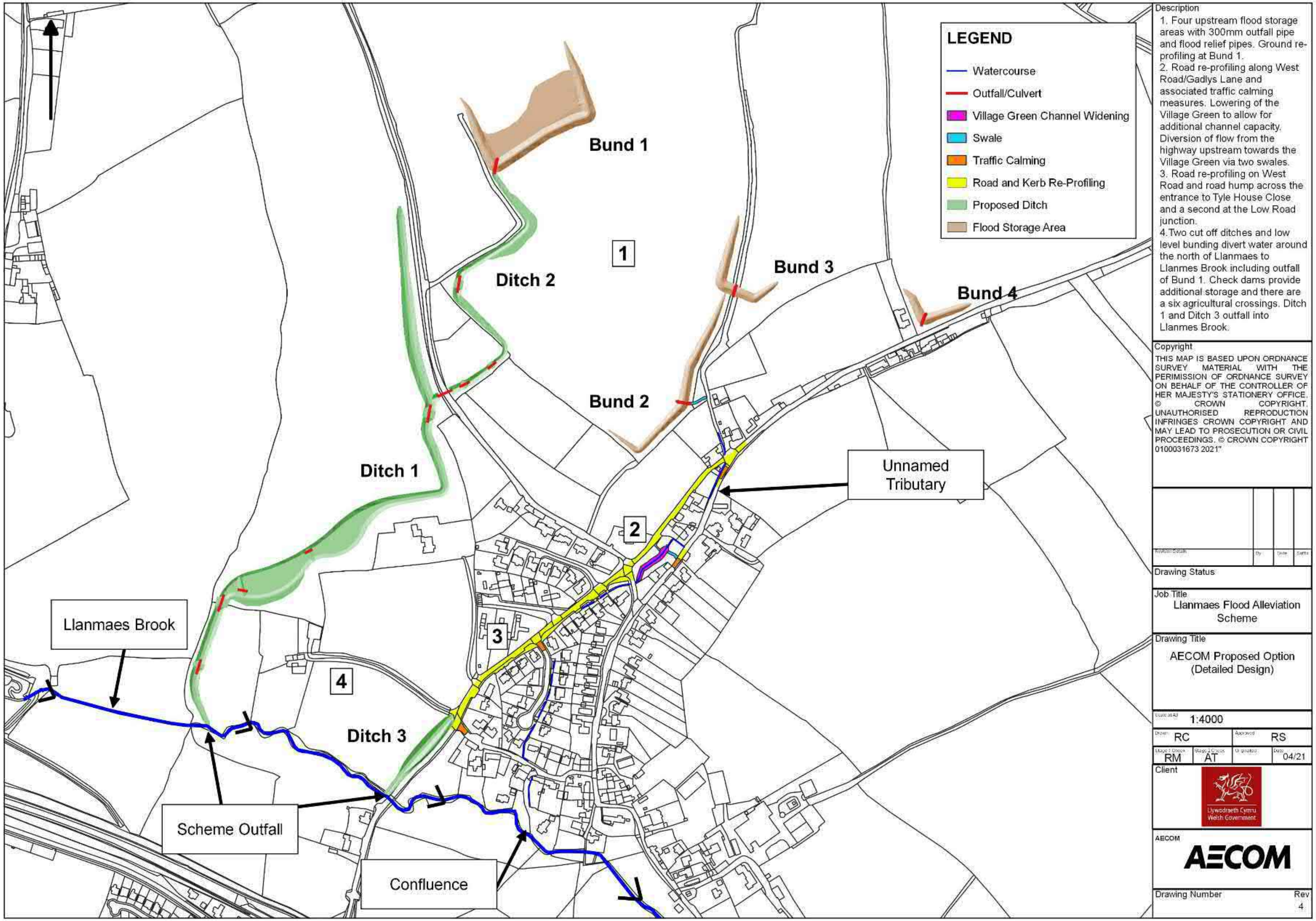

Figure 3-4: Proposed Development

4. Planning Policy and Guidance

4.1 Technical Advice Note 15

TAN 15 provides guidance which supplements the policy set out in PPW in relation to development and flooding. TAN 15 sets out a precautionary framework to direct new development away from those areas that have a high risk of flooding; and development will only be justified in these areas if it meets the criteria and tests specified in this guidance.

The operation of the precautionary framework is governed by a Development Advice Map (DAM) which consist of several zones (Table 4-1) used to trigger the appropriate planning test and definitions of vulnerable developments. The DAM Zones are based on the best available information considered adequate to determine when flood risk needs to be taken into consideration to assess the suitability of future development. It should be highlighted that the DAM is due to be replaced by the new Flood Map for Planning in Spring 2021 and guidance should therefore be reviewed as part of any future assessment. However, as the DAM is currently used for planning purposes, this has been used to inform the appraisal of flood risk as part of this report.

Table 4-1: DAM Zone designations, their associated flood risk definition and use within the precautionary framework *(source: TAN 15)*

DAM Zone	Definition	Use within the precautionary framework
A	Little or no risk of fluvial/ tidal flooding	Justification test is not applied and do not need to consider further
B	Areas known to have flooded historically evidenced by sedimentary deposits.	Used as part of the precautionary approach to indicate where site levels should be checked against the extreme (0.1% AEP) flood. No need to consider flood risks further if site levels are greater than the extreme flood level
C	Based on NRW extreme flood outline (0.1% AEP)	Indicates that flooding issues should be considered as an integral part of the decision making by the application of the justification test, including FCA
C1	Areas of Zone C which are developed and served by significant infrastructure, including flood defences	Indicates that development can take place subject to the application of the justification test, including acceptability of consequences
C2	Areas of Zone C without significant flood defence infrastructure	Indicates that only 'less vulnerable' development should be considered, subject to the application of the justification test, including acceptability of consequences. Emergency services and highly vulnerable development should not be considered.

The precautionary framework identifies the vulnerability of different land uses to flooding and classifies proposed uses accordingly as detailed in Table 4-2. This is because certain flooding consequences may not be acceptable for particular development types.

Table 4-2: Development Categories *(source: TAN 15)*

Flood Zone Definition	Use within the precautionary framework
Emergency Services	Hospitals, ambulance stations, fire stations, police stations, coastguard stations, command centres, emergency depots and buildings used to provide emergency shelter in time of flood.
Highly vulnerable development	All residential premises (including hotels and caravan parks), public buildings (e.g. schools, libraries, leisure centres), especially vulnerable industrial development (e.g. power stations, chemical plants, incinerators), and waste disposal sites.
Less vulnerable development	General industrial, employment, commercial and retail development, transport and utilities infrastructure, car parks, mineral extraction sites and associated processing facilities, excluding waste disposal sites.

According to TAN 15, new development should be directed away from DAM Zone C and towards more suitable land in DAM Zone A, otherwise to DAM Zone B, where fluvial or tidal flooding will be less of an issue.

The proposed Llanmaes FAS is located primarily within DAM Zone A (Figure 4-1) and is a water compatible development. Under TAN 15 the Justification Test is not applied and the development is considered appropriate under the requirements of national policy (Table 4-1). The DAM Zone designation is only applied to Main River watercourses and therefore the flood risk from the unnamed tributary, as ordinary watercourse, is not represented within the DAM Zones. As such Figure 4-1 is not considered to be representative of the fluvial flood risk posed to Llanmaes and hydraulic modelling has been undertaken to improve confidence in the assessment of flood risk to Llanmaes (Section 6 and Section 7).

Figure 4-1: NRW Development Advice Map (Accessed 13/04/21)

4.2 Local Development Plan

The Local Development Plan[14] provides the local planning policy framework, which was adopted by VoGC on 28th June 2017. The Plan states that Llanmaes is located within a Conservation Area and is covered by Policy MD5 which defines development within settlement boundaries. Local Development Plan policies relevant to water and flood risk are summarised below:

- MD1 – Location of New Development. New development on unallocated sites should provide a positive context for the management of the water environment by avoiding areas of flood risk in accordance with the sequential approach set out in national policy and safeguard water resources. Development will be expected to avoid unnecessary flood risk and meet the requirements of TAN 15. No highly vulnerable development will be permitted within DAM Zone C2 and development will only be considered in areas at risk of flooding where it can be demonstrated that the site can comply with the justification and assessment requirements set out in TAN 15.
- MD7 – Environmental protection. This policy seeks to ensure that development does not increase flood risk. In accordance with TAN 15, no highly vulnerable development will be permitted in DAM Zone C2. Development will only be considered in other areas at high risk of flooding where it can be demonstrated that the site can comply with the justification and assessment requirements of TAN 15.

[14] Vale of Glamorgan Local Development Plan (LDP). Available online at: http://www.valeofglamorgan.gov.uk/en/living/planning_and_building_control/Planning/planning_policy/local_development_plan/Local-Development-Plan.aspx.

4.3 Strategic Flood Consequence Assessment

No Strategic Flood Consequence Assessment for this location exists. Therefore, it has not been possible for this to be taken into consideration to support this FCA.

4.4 Preliminary Flood Risk Assessment

4.4.1 2011 Preliminary Flood Risk Assessment (PFRA) and 2017 PFRA Addendum Report

VoGC developed a Preliminary Flood Risk Assessment[15] (PFRA) in 2011 which examined the areas within the Vale of Glamorgan County that have historically suffered from flooding and potential for future flooding to identify areas with significant surface water flood risk. No indicative Flood Risk Areas have been identified within the Vale of Glamorgan County. The PFRA has been reviewed in 2017 and an addendum report was produced. The addendum report also confirms that no Flood Risk Areas are identified within the Vale of Glamorgan County. The Welsh Government set a significance threshold of 5,000 people at risk of flooding to identify a location as a Flood Risk Area. Therefore, areas identified at risk of flooding not meeting this threshold, form the basis of the Local Flood Risk Management Strategy.

4.4.2 Western Wales River Basin District PFRA, December 2018

The Western Wales River Basin District PFRA[16] was produced collaboratively by Welsh Government, NRW, the Welsh Local Government Association and Lead Local Flood Authorities (LLFAs). The PFRA assesses and identifies those areas within Wales that are most at risk of flooding from any source. The Western Wales River Basin District extends across the entire western half of Wales, from the Vale of Glamorgan in the south to Denbighshire in the north.

The report identifies areas defined as Flood Risk Areas across Wales for surface water flooding only. Swansea and Neath were the two Flood Risk Areas identified within Western Wales (as shown in Figure 4 of the PFRA), both areas are located approximately 40km and 36km from Llanmaes respectively. It has therefore been concluded that due to the distance from Llanmaes, both Flood Risk Areas would not affect the site.

4.5 Local Flood Risk Management Strategy

In 2013, VoGC developed a Local Flood Risk Management Strategy (LFRMS)[17]; which highlights the responsibilities of VoGC as LLFA with respect to flooding from surface water, ordinary watercourses and groundwater.

The Local Strategy encourages effective flood risk management by enabling people, communities, business and the public sector to work together to:

- Ensure a clear understanding of the risks of flooding and erosion, nationally and locally, so that investment in risk management can be prioritised more effectively;
- Set out a clear and consistent plan for risk management so that communities and businesses can make informed decisions about the management of the residual risk;
- Encourage innovative management of flood and coastal erosion risks, taking account of the needs of communities and the environment;
- Form links between the local flood risk management strategy and local spatial planning;
- Ensure that emergency plans and responses to flood incidents are effective and that communities are able to respond properly to flood warnings; and,
- Help communities to recover more quickly and effectively after incidents.

[15] Preliminary Flood Risk Assessment (PFRA) Vale of Glamorgan Council. Available online at: http://www.valeofglamorgan.gov.uk/Documents/Living/Highways%20&%20infrastructure/Exec-Summary-ENG.pdf.
[16] Western Wales River Basin District Preliminary Flood Risk Assessment Report. Available online at: https://cdn.naturalresources.wales/media/687969/pfra-report-western-wales.pdf
[17] Local Flood Risk Management Strategy, December 2013. Vale of Glamorgan Council. Available online at: http://www.valeofglamorgan.gov.uk/Documents/_Committee%20Reports/Cabinet/2014/14-04-28/VoGC-LFRMS----Vol-1-Main-Report.PDF.

According to the LFRMS, the PFRA refers to two major historic flooding incidents in 1998 and 2007, that were classified as having 'locally significant harmful consequences'. The 1998 flood event was due to a prolonged period of heavy rain which caused the ordinary watercourses and Main Rivers to overtop their banks. Flooding occurred in several areas across South Wales, including the inundation of seven properties within Llanmaes. On 20th July 2007, a number of locations in the Vale of Glamorgan were subject to intense rainfall including Llanmaes. Significant flooding of properties and roads were reported as watercourses and land drainage systems were unable to cope with the intensity of the event.

More recently in December 2012 and January 2013, the PFRA states that flood incidents directly impacted properties in both Llanmaes and Boverton.

4.6 Our Vale – Our Future – Vale of Glamorgan Well-being Plan 2018 – 2023

The Vale of Glamorgan Well-being Plan has been developed in accordance with VoGC's duties under the Well-being of Future Generations[18] (Wales) Act 2015. This is a unique piece of legislation which requires VoGC to 'act in a manner which seeks to ensure that the needs of the present are met without compromising the ability of future generations to meet their own needs'. The proposals in this report will enable the Council to continue to work towards the 'Well-being Outcome W02, An Environmentally Responsible and Prosperous Wales' and in particular contribute towards the Council's objective O4 of promoting sustainable development and protecting our environment as evidence for the '2015 Future Generations Act'.

4.7 Sustainable Drainage Systems (SuDS) Guidance

Since 7th January 2019, Schedule 3[19] of the Flood and Water Management Act 2010 makes SuDS a mandatory requirement in Wales for all new developments of more than one dwelling house or where the construction area is 100m^2 or more. SuDS on new development must be designed and built in accordance with the Statutory SuDS Standards published by Welsh Ministers and SuDS schemes must be approved by the local authority (VoGC) acting in its Sustainable Drainage Approval Body (SAB) role before construction work begins. Any requirement of SAB approval for the Llanmaes FAS will be discussed with VoGC.

[18] 2015 Welsh Government Future Generations Act
[19] Schedule 3 to the Flood and Water Management Act 2010. Available online at: https://www.legislation.gov.uk/ukpga/2010/29/schedule/3. Last accessed: 02/09/19

5. Sources of Flooding and Flood Risk

5.1 Assessment of Flood Risk

TAN 15 requires that all potential flood sources that could affect the Proposed Development be considered as part of an FCA. As a FAS, the intention is to reduce surface water and fluvial flood risk in Llanmaes through the control of surface water volumes and overland flow paths. As such, an assessment of flood risk to the FAS does not seem appropriate. The assessment of flood risk has therefore been carried out throughout Llanmaes village to provide an assessment of the current level of flood risk.

This chapter includes flooding from fluvial and tidal sources, directly from rainfall on the ground surface, rising groundwater, overwhelmed sewers and drainage systems. Flooding from reservoirs, canals, lakes and other artificial sources are also considered.

5.2 Surface Water

Overland flow routes are primarily created from rainfall that fails to infiltrate the surface and travels over ground; this is exacerbated where the permeability of the ground is low due to the type of soil/ geology (such as clayey soils) or urban development. Surface water is also promoted in areas of steep topography which can rapidly convey water that has failed to penetrate the surface.

NRW's surface water flood risk maps indicate that areas around the Village Green and Low Road within Llanmaes are located within a high risk area of surface water flooding (Figure 5-1). Section 3.5 has demonstrated through anecdotal evidence that Llanmaes suffers from surface water flooding on a regular basis which is exacerbated by the lack of capacity within the unnamed tributary channel. Hydraulic modelling has been undertaken to assess in detail the surface water flood risk to Llanmaes and the impacts of the proposed FAS. Section 6 outlines the methodology and hydraulic modelling results which provide the baseline flood risk.

This initial assessment indicates that the surface water flood risk from surface water is considered high.

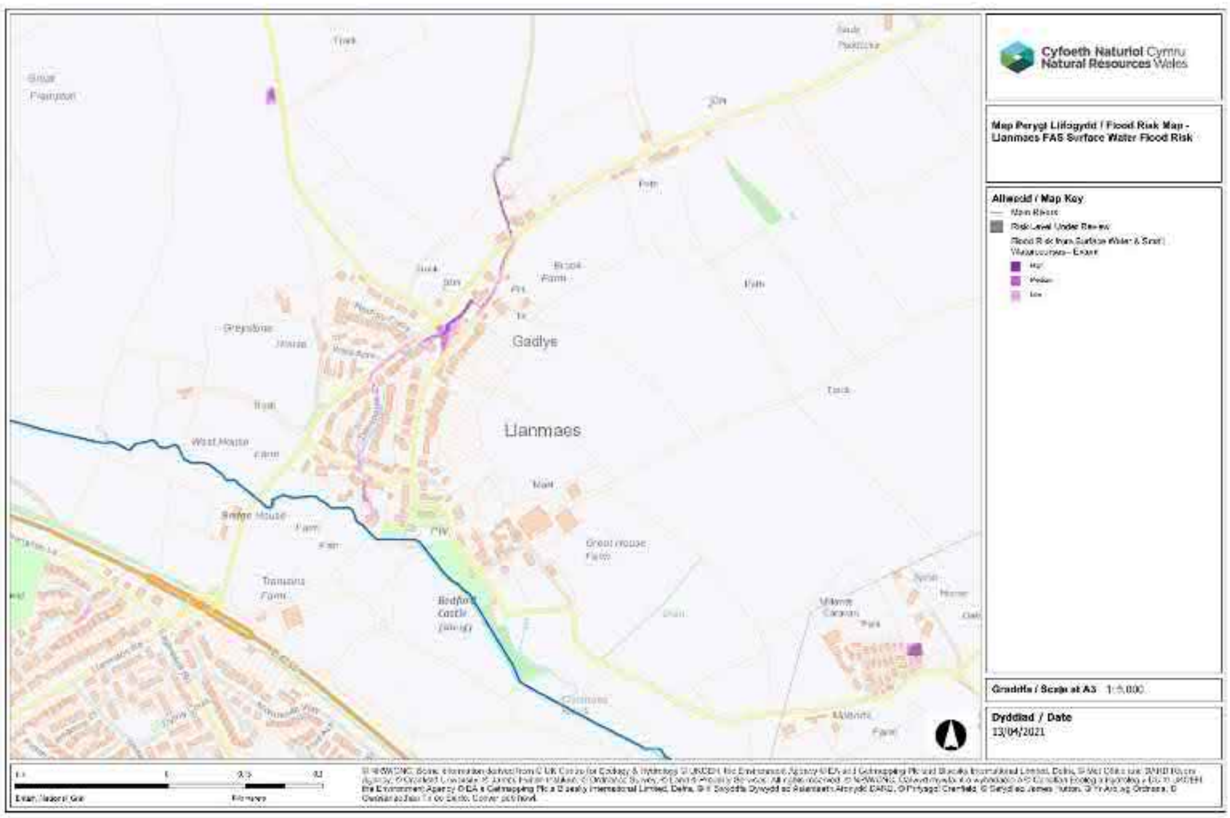

Figure 5-1:NRW Surface Water Flood Risk Map (13/04/21)

5.3 Fluvial and Tidal

As highlighted in Section 4.1, the majority of Llanmaes is located within DAM Zone A, which are areas classified as having little or no risk of tidal/fluvial flooding. The western boundary of Llanmaes is classified as being in DAM Zone C, an area which has been assessed as having a high risk of fluvial/tidal flooding. Figure 5-2 shows the NRW flood risk map which identifies one property at low risk of flooding from main river within Llanmaes. The NRW flood risk maps do not identify fluvial flood risk from ordinary watercourses. The fluvial flood risk in Llanmaes is primarily from the unnamed ordinary watercourse that flows through the centre of the village and this has a strong interdependency with surface water flooding sources which are conveyed to the village through the surrounding landscape. Therefore, it is prudent to highlight, that due to this high degree of correlation between fluvial and surface water flood risk, that both elements are considered further within this report as part of the surface water assessment (Section 6 and Section 7).

In agreement with the surface water assessment, flood risk from fluvial sources is also considered high.

There is no flood risk from tidal sources, given the relative elevation of Llanmaes and distance from the Bristol Channel. As such, no further discussion is presented within this FCA.

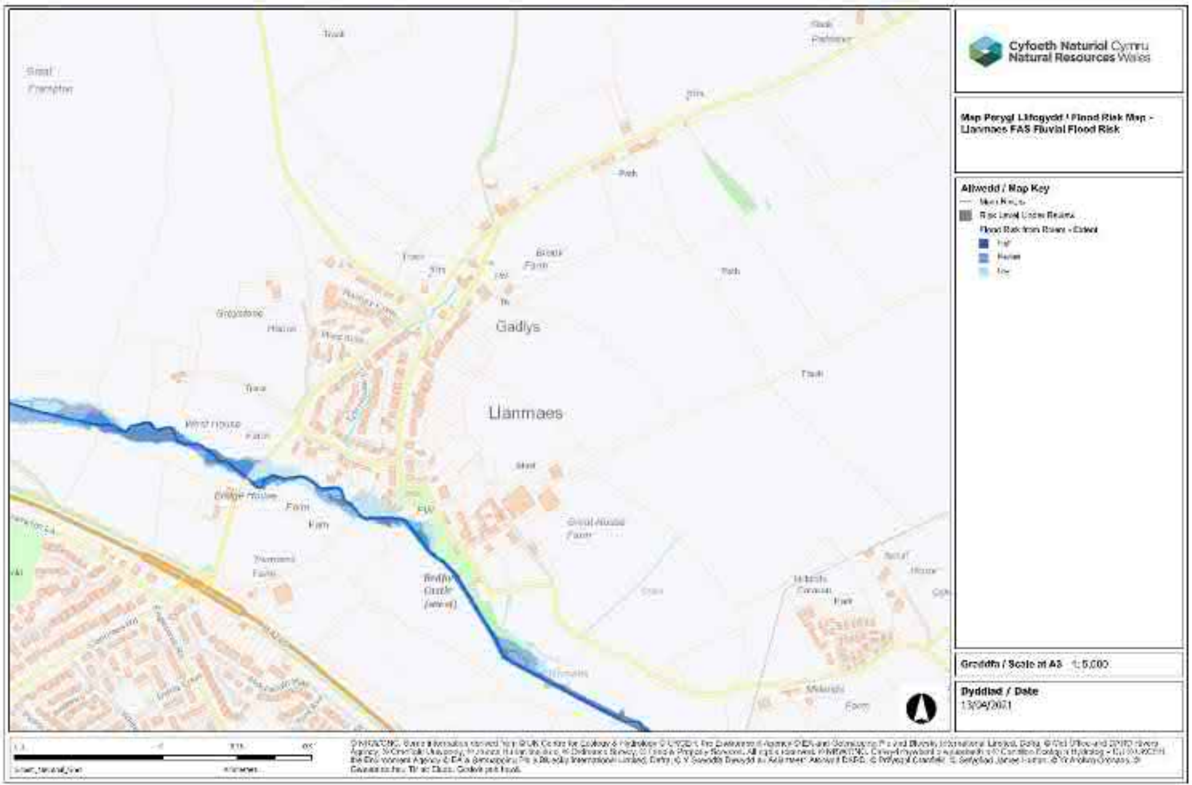

Figure 5-2: NRW Flood Risk from Rivers Map (Accessed 13/04/21)

5.4 Sewer

Flooding can occur as a result of infrastructure failure, e.g. blocked sewers or failed pumping stations. Sewer flooding can occur when the system surcharges due to the volume or intensity of rainfall exceeding the capacity of the sewer, or if the system becomes blocked by debris or sediment.

The LFRMS states that sewer flooding occurred in December 2012 and January 2013, in combination with surface water, fluvial and groundwater flooding across Vale of Glamorgan. No further information with regards to the exact location where the sewer flooding occurred is provided. Sewer flooding was reported in Llanmaes to VoGC in November 2019 due to surcharging manholes.

Anecdotal evidence suggests that the surface water sewer network can become overwhelmed and manholes near Pond Villa are known to have surcharged during high rainfall events. The surface water sewer network in Llanmaes partly drains into the unnamed tributary and ultimately outfalls into Llanmaes Brook. During flood events this outfall may become impeded due to high river levels. Based on this assessment the flood risk from sewer sources is considered medium risk.

The capacity of the surface water sewer network is unknown and therefore to assess the surface water flood risk it has been assumed that the network is at capacity. To this end, the flood risk from sewer sources is considered as part of the surface water flood risk assessment and is not considered further.

5.5 Groundwater

Groundwater flooding occurs where groundwater levels rise above ground surface levels. The geology and topography have a major influence on where this type of flooding takes place; where it is most likely to occur in low-lying areas underlain by permeable rocks. Very little historic evidence of this type of flooding is available and the predicted future impacts are primarily based on generic national geological mapping.

Groundwater flood events in Wales are rare according to the Western Wales PFRA. Generally, the geology and steep topography in Wales mean that groundwater flooding is very unlikely to occur. Flooding recorded as groundwater may actually be from disused mine workings. Whilst this remains a concern for some LLFAs, it still remains a very low likelihood. Since 2011, there have been no recorded events of groundwater flooding within the Western Wales River Basin District.

According to the LFRMS, localised groundwater flooding is reported to have occurred in four villages in the Vale of Glamorgan, but not Llanmaes. Figure 4 of the LFRMS shows that Llanmaes is partially within an area <25% susceptibly to groundwater flooding. Given the current available data within the LFRMS, it is unlikely that flooding would occur solely from groundwater sources however, periods of high groundwater may increase flow from the groundwater issues located throughout the village and contribute to the overall volume of water entering Llanmaes.

To allow for difficulties in quantifying any groundwater contributions within Llanmaes, sensitivity analysis has been carried out on the Baseline hydraulic model to assess uncertainty in the surface water volumes reaching Llanmaes (Section 8.4).

The risk of groundwater for the site is considered to be ‘low’ and is not considered further within this report.

5.6 Artificial Sources

Artificial flood sources include raised channels such as canals or storage features such as ponds and reservoirs.

According to the Western Wales PFRA, there have been no incidents of reservoir flooding in Wales since 2011. In addition to this, the NRW Flood Risk from Reservoirs Map indicates that Llanmaes does not coincide with a flood extent associated with reservoir failure with the nearest extent is approximately 3.5km east of Llanmaes. Therefore, it is considered that there is no risk of flooding from artificial sources and this is not considered further within this report.

5.7 Summary

The assessment in this FCA has focused on the flood risk to the village of Llanmaes to identify which mechanisms of flooding are present within the village. Hydraulic modelling has been undertaken to quantify the pluvial/fluvial flood risk to Llanmaes and provide a robust baseline from which to assess the proposed FAS (Section 6 and Section 7).

The initial assessment prior to hydraulic modelling of flood risk to Llanmaes is:

- Surface water - High risk
- Fluvial – High risk
- Sewer flooding - Medium risk
- Groundwater - Low risk
- Artificial Sources – No risk
- Tidal - No risk

6. Pluvial Hydraulic Modelling and Assessment of Baseline Flood Risk

6.1 Overview

From a review of flood history at Llanmaes, it is clear that the primary mechanism for flooding throughout the village is overland flow in conjunction with the limited capacity of the unnamed tributary through the village. AECOM has applied professional judgment of experience within similar case studies, adopting a methodology inclusive of a direct rainfall (pluvial) model of the catchment contributing to Llanmaes. It was determined that using more conventional fluvial based 'point inflow' hydraulic modelling through Llanmaes, would not be representative of the real issues posed to the region and could therefore produce an unreliable estimation of flooding and resultant scheme taken forward. This methodology was agreed with NRW at a meeting in February 2018.

6.2 Model development

AECOM was provided with the NRW approved 2017 NAR FCA ESTRY-TUFLOW pluvial hydraulic model of the Boverton Brook catchment. Following a meeting with NRW in July 2017[20] it was agreed that AECOM would adopt a revised Baseline hydraulic model representation under the assumption that the construction of the NAR and all associated flood mitigation measures has taken place. NRW were accepting of this approach. The construction of the NAR and associated flood mitigation measures was completed in March 2019 and therefore the representation in the hydraulic model is consistent with the present-day conditions.

The pluvial hydraulic model was augmented using site specific survey and topographic data supplied by VoGC to include the unnamed ordinary watercourse that flows through Llanmaes to create an updated baseline. Throughout the option development further site-specific surveys have been collected by AECOM to improve the accuracy of the design and hydraulic model. Figure 6-1 shows the pluvial model extents used in this study. The Baseline model grid resolution was reduced from 4m to a 2m grid and extents were reduced to the Llanmaes Brook catchment to ensure that a suitable balance between model accuracy and practical simulation times were reached. Full details on the development of the Baseline hydraulic model can be found in the Hydraulic Modelling Report in Appendix C.

The Baseline hydraulic model has undergone review by NRW throughout the model build process. NRW have agreed that the Baseline model provides a suitable representation of flood risk within the Llanmaes Brook catchment (08/01/2019). To ensure that an assessment of any downstream impacts of the scheme were understood, a sensitivity analysis was carried out on both the Baseline and Proposed Option hydraulic model with the rainfall catchment extended to include the Boverton Brook catchment (Section 7.4). This methodology was also agreed with NRW (08/01/2019)

[20] AECOM (2017) Llanmaes FAS – NRW revised Minutes 170707

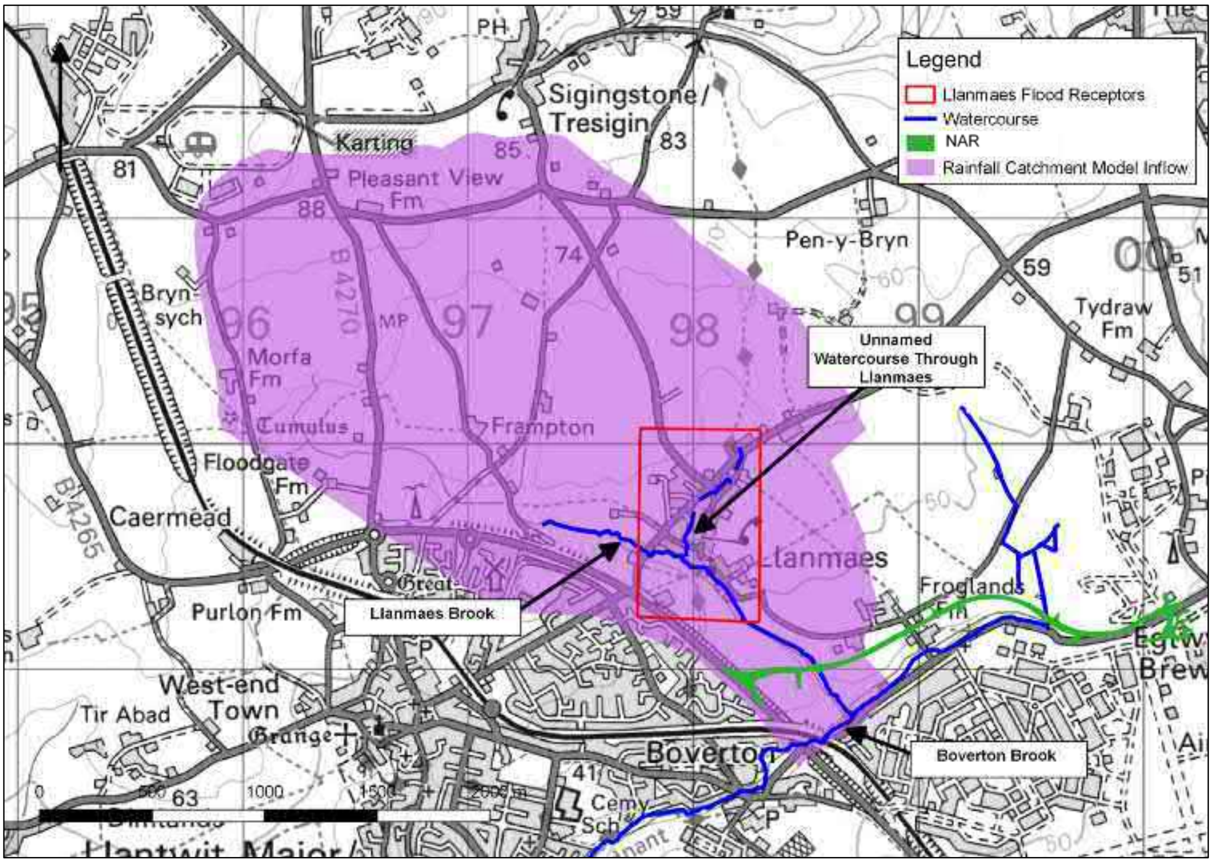

Figure 6-1: Hydraulic model extents

6.2.1 Hydrology

Hydrological analysis was completed to form rainfall hyetographs for events with an Annual Exceedance Probability (AEP) of 20% AEP, 1% AEP, 1% AEP + 30% climate change, 1% AEP + 75% climate change and 0.1% AEP using the Microdrainage software package. For each AEP, hyetographs were created for storms with durations of 60, 180 and 360 minutes with a winter profile and an assessment of the critical storm duration undertaken. Examination of flood depths and extents demonstrated that the 60 minute storm duration was associated with the largest extent/depth of inundation and should be considered as the critical storm duration for the refined Llanmaes pluvial model (Appendix C).

In order to calculate effective rainfall for application within a pluvial hydraulic model, it is necessary to account for losses attributable to infiltration and the capacity of the surface water drainage network within the catchment. Analysis of satellite imagery and land cover information within GIS demonstrated that the Boverton Brook catchment comprised of 95% undeveloped land, with less than 5% of the modelled area being characterised by impermeable surfaces. Therefore, the approach adopted assumed that all losses within the model domain were attributable to infiltration. Due to the predominately rural nature of the modelled catchment, losses due to surface water drainage network were not represented. Following the analysis described in Appendix C, a runoff coefficient of 0.3 was selected and applied to all rainfall hyetographs to represent infiltration loses.

The Entec 2009 FCA[21] report indicates that the SPRHOST was adjusted from 11.7% (FEH CD value) to an SPR of 31.7%, based on the investigations into percentage runoff undertaken, which indicated a higher level of percentage runoff. This higher rate agrees with coefficients calculated as part of this investigation.

[21] ENTEC 2009 St.Athan Flood Consequence Assessment

6.2.2 Climate Change

Climate change allowances were taken from the Welsh Government's 2016 guidance for FCAs[22]. Llanmaes Brook is located within the Western Wales river basin district, whereby the central estimate of potential change by the 2080s to peak river flows is +30% for this region, and the upper end estimate is +75%. These climate change allowances have been applied to the pluvial model, under agreement with NRW (07/07/2017), to maintain consistency with the existing NAR model and allow direct comparison of results. This is also recommended due to the strong interdependency between pluvial and fluvial sources as a result of the assessment of flood history in the village.

6.2.3 Design Events

The hydraulic model has been simulated for a range of design events to ensure that the assessment of flood risk to and from the development is robust. The following design events have been used in this study 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP + 30% climate change, 1% AEP + 75% climate change and 0.1% AEP event. This range of design events provides a robust assessment of flood risk to the study area in line with the requirements of NRW modelling for FCA guidance[23].

6.3 Baseline Hydraulic Model Results

The direct rainfall model was first simulated to identify the primary flow paths contributing to Llanmaes Brook and also the urbanised area of Llanmaes village, in order to understand the key mechanisms and flow paths contributing to flooding in the village, validating them against available flood history information.

Baseline model results are detailed in Appendix C and summarised in Section 6.3.1 to Section 6.3.3

6.3.1 Baseline Flow Paths

Figure 6-2 shows the maximum unit flow map for the 1% AEP + 30% climate change event. This demonstrates that, the unnamed tributary through Llanmaes directs flow from the fields at the north end of the village through the Village Green, along West Road and down Tyle House Close before passing beneath Low Road, reaching a confluence with Llanmaes Brook south west of Tara House. As a result, overland flow has been observed within the model to be passing through residential properties along Tyle House Close, Low Road and Tara House. Model results indicate that the existing channel capacity is exceeded during even the lowest magnitude event simulated (20% AEP).

A significant overland flow path propagates in a southerly direction from the agricultural fields to the north of the village and is the primary contributor of flows entering Llanmaes. During the 1% AEP + 30% climate change scenario, this reaches a peak of approximately 4.6m^3/s which cannot be conveyed in-channel by the low capacity of the unnamed tributary. Figure 6-2 also shows a number of other smaller flow paths entering Llanmaes from the surrounding fields where they are concentrated by the graded road network towards the Village Green. In particular West Road, Gadlys Lane and Sigingstone Lane act as primary conduits for overland flow to the north of Llanmaes where collection of overland floodwater is evident.

At the southern end of Llanmaes, properties on Tyle House Close, Low Road and surrounding Tara House are impacted by overland flows from West Road and the surrounding fields. Overland flow is directed towards a low spot on Low Road then ultimately south towards Llanmaes Brook. Model results show that during events greater than 20% AEP, flooding is exacerbated by overtopping of the right bank of the unnamed tributary at Low Road and left bank immediately upstream of the Llanmaes Brook outfall culvert.

[22] Welsh Government 2016 Guidance for Flood Consequence Assessments - Climate Change Allowances. Accessed from https://gweddill.gov.wales/topics/planning/policy/policyclarificationletters/2016/cl-03-16-climate-change-allowances-for-planning-purposes/?lang=en
[23] NRW 2021 Natural Resources Wales / Developing in a flood risk area. Accessed from: https://naturalresources.wales/guidance-and-advice/business-sectors/planning-and-development/advice-for-developers/developing-in-a-flood-risk-area/

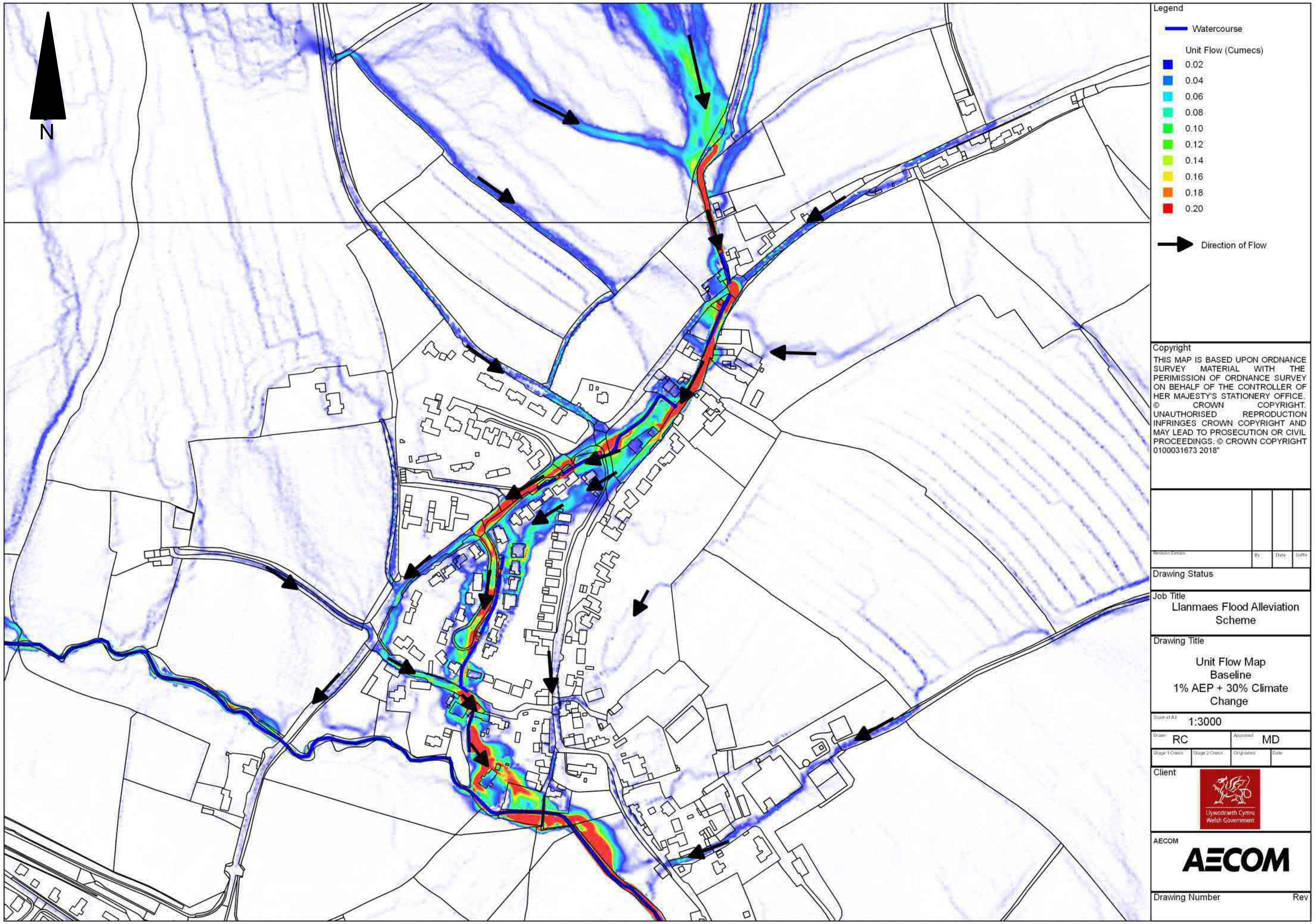

Figure 6-2: Surface Water Flow Paths, Baseline, 1% AEP + 30% Climate Change

6.3.2 Baseline Flood Depths

The maximum flood depths for each design event have been mapped to demonstrate the level of flooding within Llanmaes (Appendix C). Figure 6-3 shows that during the baseline 20% AEP event there is flooding around the Village Green to a depth of approximately 0.1m-0.3m. This is consistent with reported flood events whereby this area of the village is inundated approximately every five years[24]. At the southern end of the village, flood depths are approximately 0.1m-0.3m on Low Road and the area around Tara House reaches depths of 0.1m-0.5m during the 20% AEP event. The model results estimate that 19 properties are affected by flooding during this event (Table 6-1).

The 1% AEP + 30% climate change scenario baseline results show that a significant amount of flooding in Llanmaes particularly around The Pump, The Croft, The Village Green, Tyle House Close and Tara House where flood depths reach between 0.4m-0.5m (Figure 6-4). The largest extent of flooding is at the junction of Sigingstone Lane and West Road where there is a combination of out of bank flow and overland flow from the surrounding highways that are attributable to flood depths. At the southern end of the village, flooding at Tyle House Close and Low Road can be seen to reach between 0.2m-0.4m during the 1% AEP + 30% climate change scenario. The largest flood depths in this part of the village are recorded on Low Road where both the highway and properties are inundated.

To quantify the number of properties that flood within the village, it is proposed that a property at risk of flooding is defined as one that shows internal flooding to a depth greater than 0.05m, due to the shallow depth nature of a catchment wide direct rainfall assessment. Table 6-1 shows that the model estimates that 61 properties are affected by flooding during the 1% AEP + 30% climate change scenario.

Table 6-1: Properties affected by flooding

Annual Exceedance Probability (AEP)	Number of Properties Affected by Flooding
20%	19
10%	27
5%	31
2%	45
1% + 30% CC	61

[24] Vale of Glamorgan Council, 2009 Project Appraisal Report

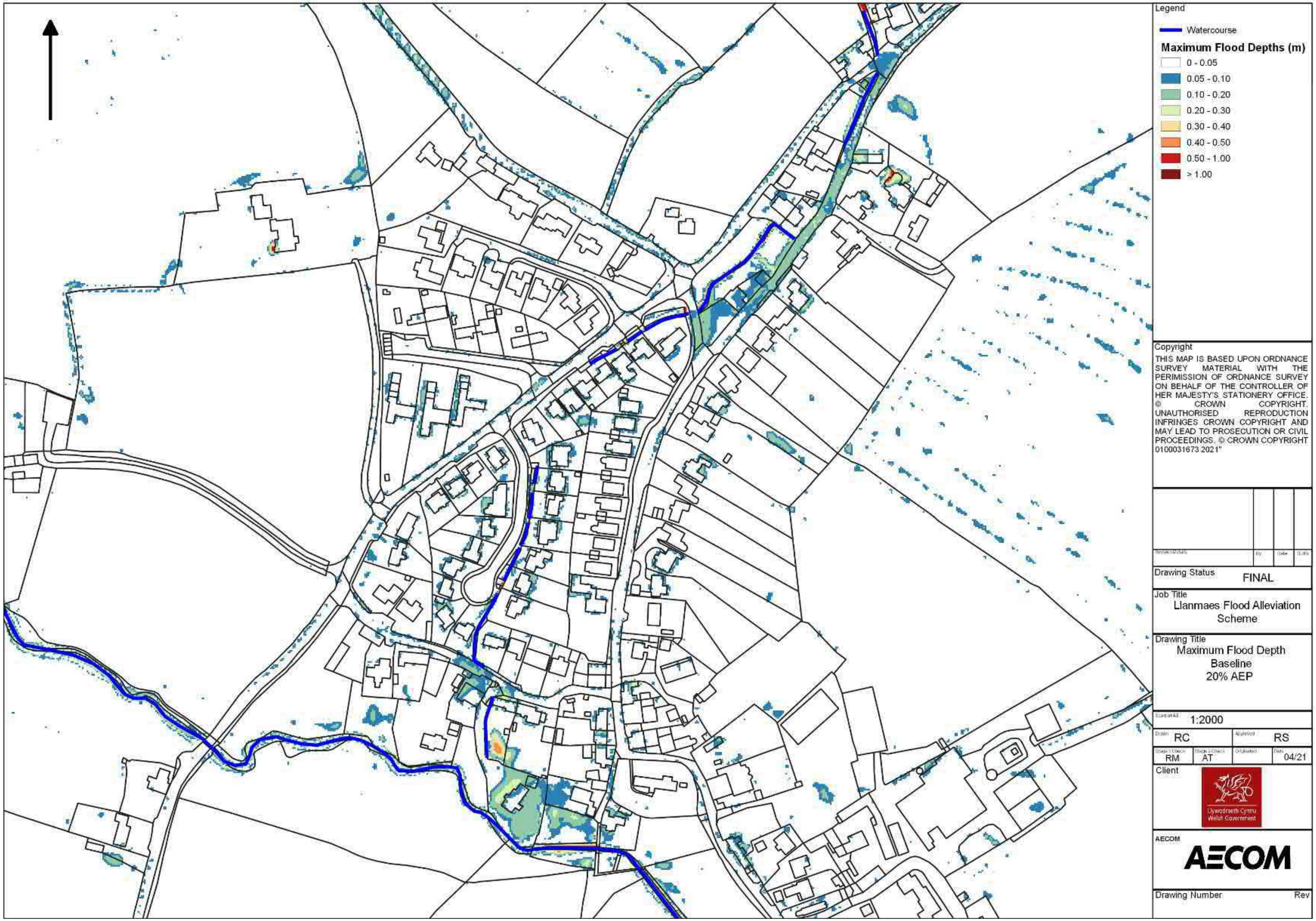

Figure 6-3: Maximum Flood Depths, Baseline, 20% AEP

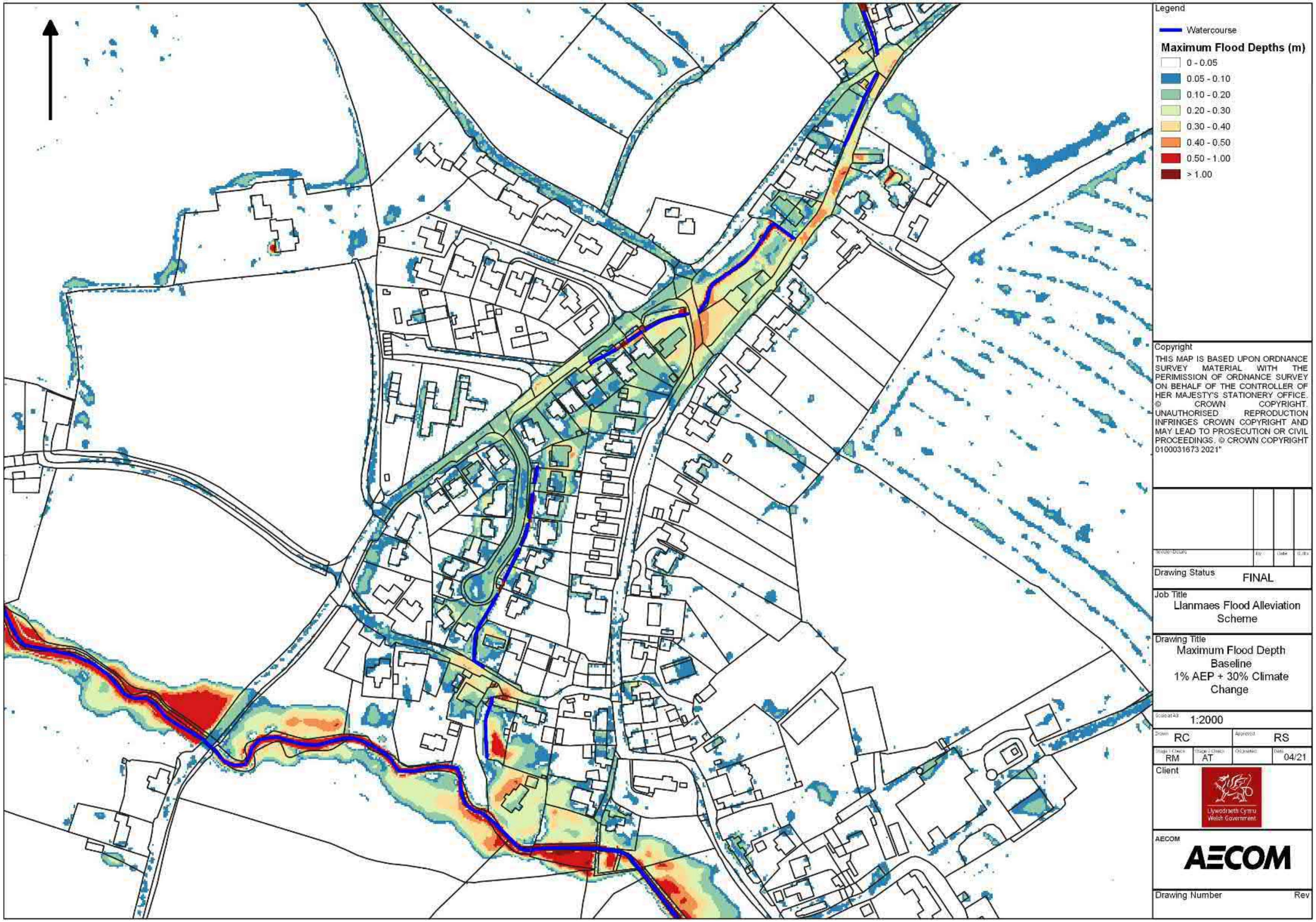

Figure 6-4: Maximum Flood Depths, Baseline, 1% AEP + 30% Climate Change

6.4 Verification

At the time of writing there is no hydrometric data available for the Llanmaes Brook catchment to quantitively verify the Baseline hydraulic model. Therefore, a qualitative approach has been taken to assess the flooding mechanisms within the hydraulic model against known flood events.

Figure 6-5 shows photographs of flooding events in December 2012 and February 2018 at locations throughout the village. Anecdotal evidence indicates that the culvert beneath West Road at the north end of the village becomes overwhelmed during flood events and both Gadlys Lane and West Road act as conduits towards the Village Green. Further flood events in November 2019, October 2020, and December 2020 have led to property flooding in Llanmaes. For the purpose of this study the December 2012 and February 2018 events have been used based on the available information at the time of writing.

The model results demonstrate that the open channel and culvert network through Llanmaes creates a series of constrictions within the network which result in backing up of flow, resulting in overtopping of the banks. During the 20% AEP event, the culvert beneath West Road, at Rose Cottage, beneath Low Road and the Llanmaes Brook Outfall (Figure 6-3) all exceed capacity, contributing to out of bank flow. This is supported by anecdotal evidence where the undersized 0.375m diameter culvert at Rose Cottage has been seen to overtop regularly, contributing to highway and property flooding.

Model results presented in Section 6.3 clearly show that the key mechanisms of flooding, overland flowpaths and restricted conveyance in the urbanised region, are represented in the model. Baseline hydraulic model results were presented to the VoGC Drainage Team (10/10/17) and it was agreed that the mechanism of flooding is consistent with local reports.

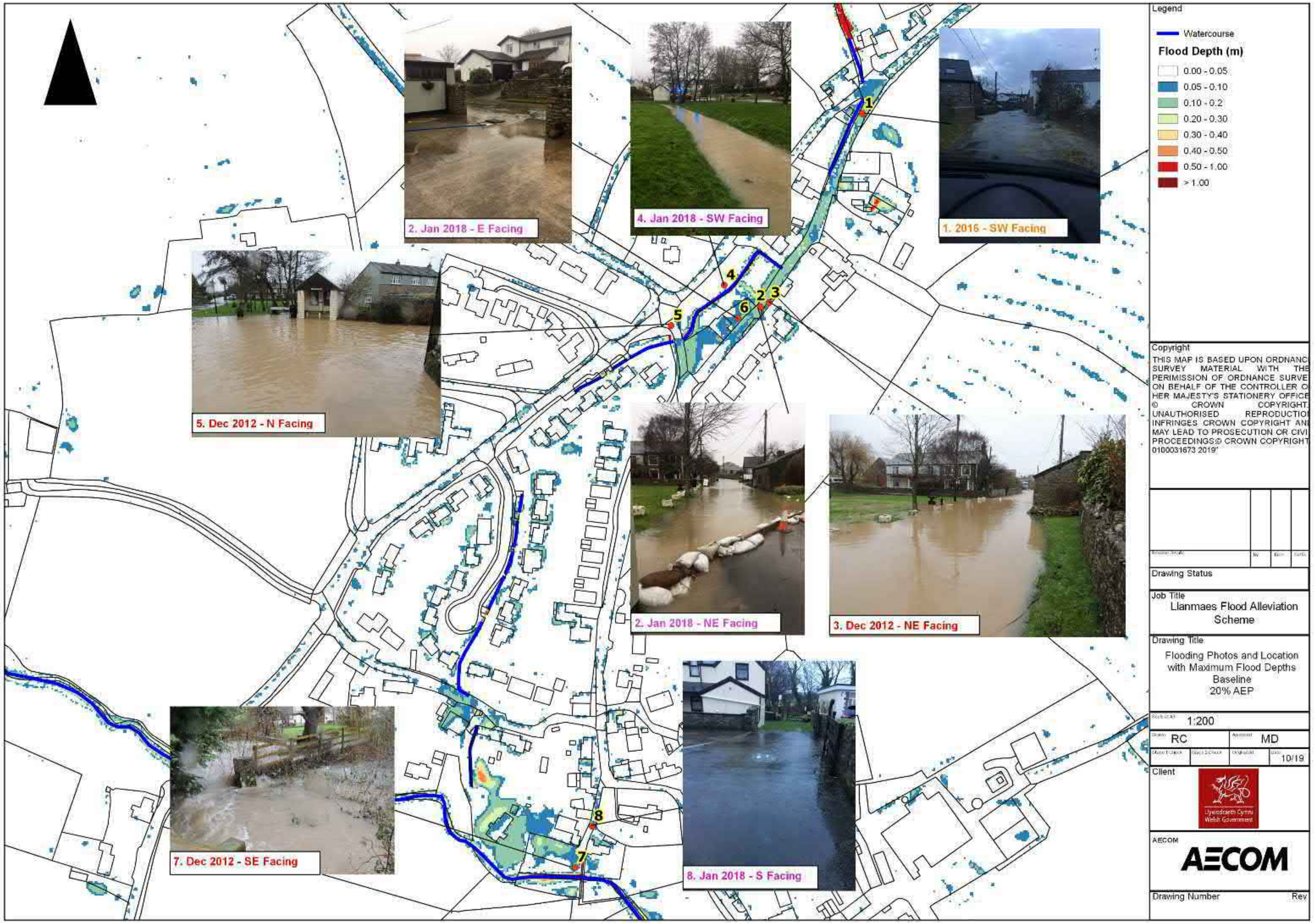

Figure 6-5: Flooding Photos and Locations

7. Pluvial Hydraulic Modelling and Assessment of Proposed Option Flood Risk

7.1 Proposed Option Model Development

Through the modelling process it became apparent that the most effective way to reduce flooding within Llanmaes was to intercept overland flow as close to the source as possible, upstream of the village, rather than trying to control it once it has entered Llanmaes where there is little space to introduce effective measures.

AECOM used an iterative process to first explore the 2014 OAR solution and then develop a series of flood mitigation measures to reach the proposed option. Table 71 shows the key iterations within the development of the scheme and AECOM has consulted with both NRW and VoGC throughout the scheme development (Section 2.4). NRW have provided positive comments and agreed at Stage 5 that the presented scheme at Stage 5 does not cause detriment downstream of Llanmaes. The options have been developed further at Stage 6 and Stage 7 through consultation with VoGC and landowners to assist with the detailed design process (Appendix B)

Table 7-1: AECOM Llanmaes FAS Proposed Option Development

Option #	Mitigation Option	Description	Comment
1.	OAR (2014) Solution	Large 900mm diameter flood relief culvert beneath and along West Road from The Pump to Llanmaes Brook, downstream attenuation storage, improved highways drainage and flood bund in field to the east of Llanmaes.	Does not provide satisfactory flood risk reduction within Llanmaes, exceptionally high construction cost, large degree of disruption to community of Llanmaes and has unviable downstream storage area.
2.	Upstream Storage (interception)	Flood storage intercepting primary overland flow paths upstream of Llanmaes. It was determined that only storage areas which collected greater than 1000m^3 would be taken forward for consideration. The total number of storage areas to be taken forward is 4.	Provides a significant reduction in flood risk to Llanmaes. However, this would not solve flooding in isolation but would prove to be effective as part of a combination with other mitigation measures.
3.	Refinement of Option #2 and Highway Reprofiling	Option #2 in conjunction with reprofiling of West Road, making more effective use of existing conveyance routes through the village.	Further reduces flood risk throughout Llanmaes. Increased residual risk recorded at properties at Low Road and Tara House, which need to be protected against.
4.	Combination of Option 3 and flood walls at Low Road and Tara House.	As per Option #3 with the inclusion of 0.7m flood walls on Low Road and 1.6m along Llanmaes Brook near Tara House	Provides significant reduction in flood risk throughout Llanmaes with no residual impact of flooding compared to the baseline design event. Not all properties could be mitigated against for the design event. This is explained further within Section 5.2.
5.	Refinement of flood walls, attenuation storage areas (Option #4), and road profiling	Utilises flood storage areas within agricultural fields to the north and up-catchment of Llanmaes in conjunction with a series of minimally disruptive highways improvements within the village and additional conveyance measures on Llanmaes Brook	Provides significant reduction in flood risk throughout Llanmaes with no residual impact of flooding compared to the baseline design event. Hydraulic model reviewed by NRW (08/01/19)
6.	Refinement of attenuation storage areas (Option #5), refinement of West Road re-profiling, addition of interception ditches north of Llanmaes, Village Green swale improvements and removal of flood walls.	Similar to Option #5 with the inclusion of an interception ditch and storage to the north of the Village. Improved conveyance into Village Green from the surrounding roads, ditch outfall into Llanmaes Brook from West Road.	Provides significant reduction in flood risk throughout Llanmaes with no residual impact of flooding compared to the baseline design event. Submitted to VoGC for detailed design review December 2019.
7.	Detailed Design refinement of location of attenuation storage areas and cut off ditches following discussions with VOGC and landowners	Similar to Option #6 with improved conveyance and storage through cut off ditches and configuration of Village Green.	Provides significant reduction in flood risk throughout Llanmaes with no residual impact of flooding compared to the baseline design event. Assessed within this FCA.

7.2 Proposed Option Model Results

Once the flood mitigation measures specified in Section 3.6 were included within the hydraulic model, the Proposed Option was simulated using the 60 minute storm duration for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP + 30% climate change, 1% AEP + 75% climate change and 0.1% AEP events. The full suite of Proposed Option modelling results can be found in the accompanying hydraulic modelling report (Appendix C).

7.2.1 Flood Depth Difference

To understand the flood risk benefits, inclusive of any detrimental impact, caused by the construction of the Proposed Option, the modelled flood depths results have been compared with the Baseline model results. Figure 7-1 shows a comparison between the Proposed Option and Baseline 1% AEP + 30% climate change design event. The model results show that there is a general reduction in flood depths of between 0.1m-0.2m throughout Llanmaes as a result of the scheme during the 1% AEP + 30% climate change event. The largest benefits can be seen around Tyle House Close, Low Road and Tara House where flood depths are reduced by approximately 0.2m-0.3m. This pattern of a reduction in flood depths throughout Llanmaes is found in all of the design events simulated (Appendix C). This demonstrates that through reducing the volume of water reaching Llanmaes, using upstream storage, ditches and maintaining overland flow routes within the existing highway there is a significant flood risk benefit available to the village during flood events.

To illustrate the magnitude of the reduction in overland flow entering Llanmaes, flow hydrographs were compared between the Proposed Option and Baseline scenarios at locations throughout the village shown in Figure 7-2. Figure 7-3 shows that the overland flow hydrograph entering the upstream end of the village (Location A) is significantly reduced from a peak flow of 4.6m^3/s in the Baseline Scenario to 0.6m^3/s in the Proposed Option Scenario. Hydraulic model results presented in Appendix C indicate that there is also a reduction in the flow hydrograph on Tyle House Close (Location B) and West Road (Location C) whilst downstream of the West Road/Low Rd junction (Location D) the flow hydrograph is increased within the highway and outfall ditch (Ditch 3). This demonstrates that the Proposed Option is effective at diverting overland flow away from flood risk receptors and maintaining water within the highway as intended.

Conversely, the hydraulic model results indicate that there is an increase in flood depths within the designated attenuation areas, Village Green, West Road and within both ditches when compared to the baseline (Figure 7-1). This is evident across all design events simulated for this study up to and including the 0.1% AEP event. The increases in flood depths within the surrounding agricultural fields are all within land under private landownership. Consultation with private landowners and VoGC is currently ongoing with positive responses across the majority of landowners. VoGC Estate department, AECOM and VoGC Land Agent are also involved in the discussions, to reach an agreement with the land owners to facilitate the scheme. The locations of all of the flood storage area bunds and cut off ditches have been informed through discussion with private landowners, VoGC and AECOM.

It is noted that model results estimate a small increase in maximum flood depths within the Llanmaes Brook floodplain, upstream of Tara House, for all events of greater magnitude than the 20% AEP (Appendix C, Section 6.1.1). This is observed in Figure 7-1 where there is an increase in maximum flood depths to agricultural land at the Ditch 1 outfall and on the upstream face of the West Road bridge of +0.01m to +0.03m. Further to this there are two locations within Llanmaes village where there is an increase in maximum flood depths of up to +0.02m within during events lower than 1% AEP. Investigation of these locations indicates that this is predominately as a consequence of hydraulic modelling limitations and not representing low level walls within the hydraulic model. This is discussed in detail within the hydraulic modelling report in Appendix C and residual flood risk from the scheme is discussed in further detail in Section 8.

It has been demonstrated that the Proposed Option provides a significant reduction in the overall flood depths throughout Llanmaes across all simulated AEP events (Appendix C). However, due to the volume of water entering Llanmaes and the limited capacity of the unnamed tributary channel, the results show that all flood risk could not be completely mitigated against for some properties, although this is not exacerbated by the introduction of the Proposed Scheme. This is illustrated in Figure 7-4 that shows for the 1% AEP + 30% climate change event, maximum flood depths inundating properties has been reduced to approximately 0.2m-0.4m and is limited to a relatively small area throughout the village. Residual flood risk to properties is discussed further in Section 8.1.

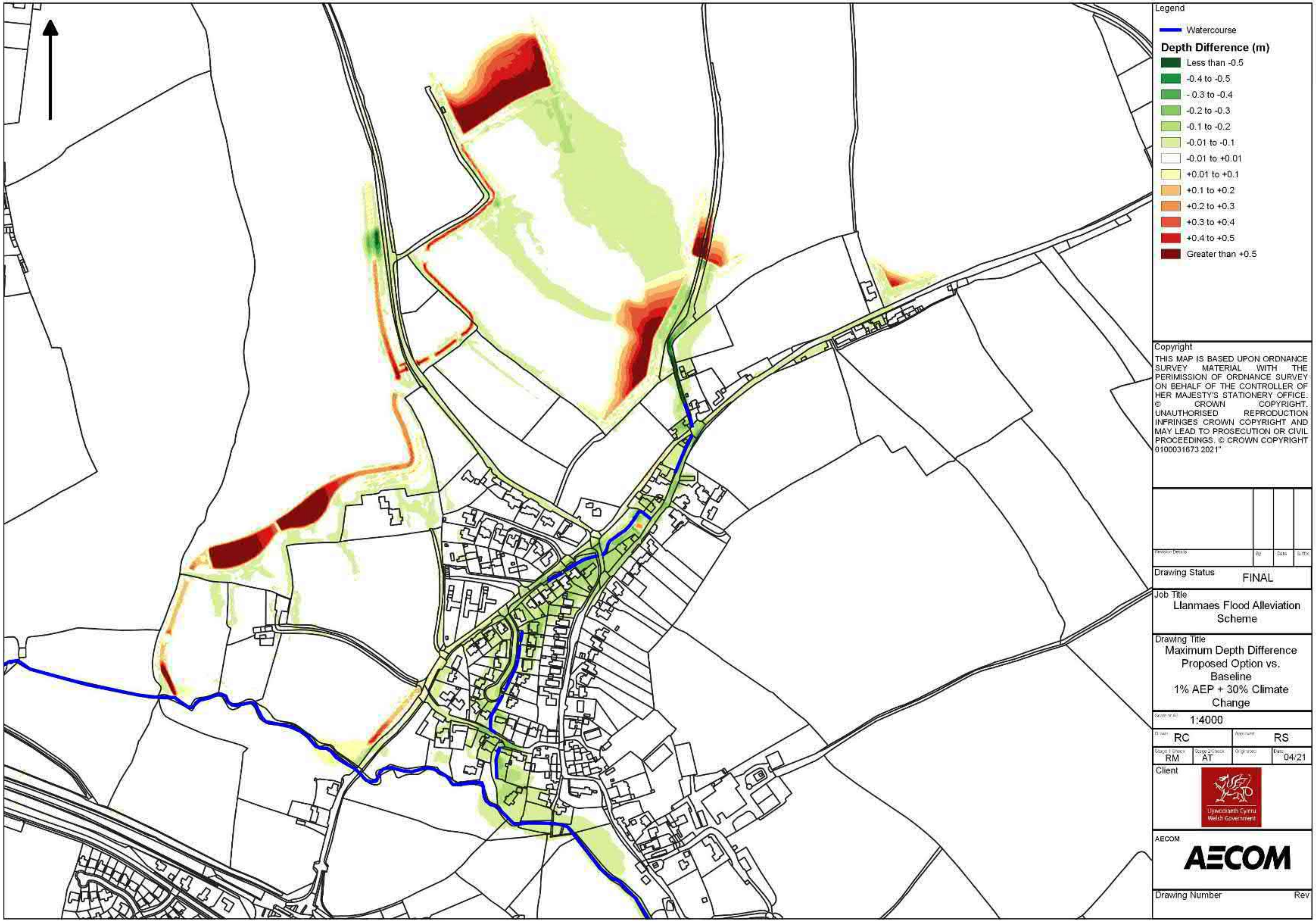

Figure 7-1: Depth Difference Map, Proposed Option vs. Baseline, 1% AEP + 30% Climate Change

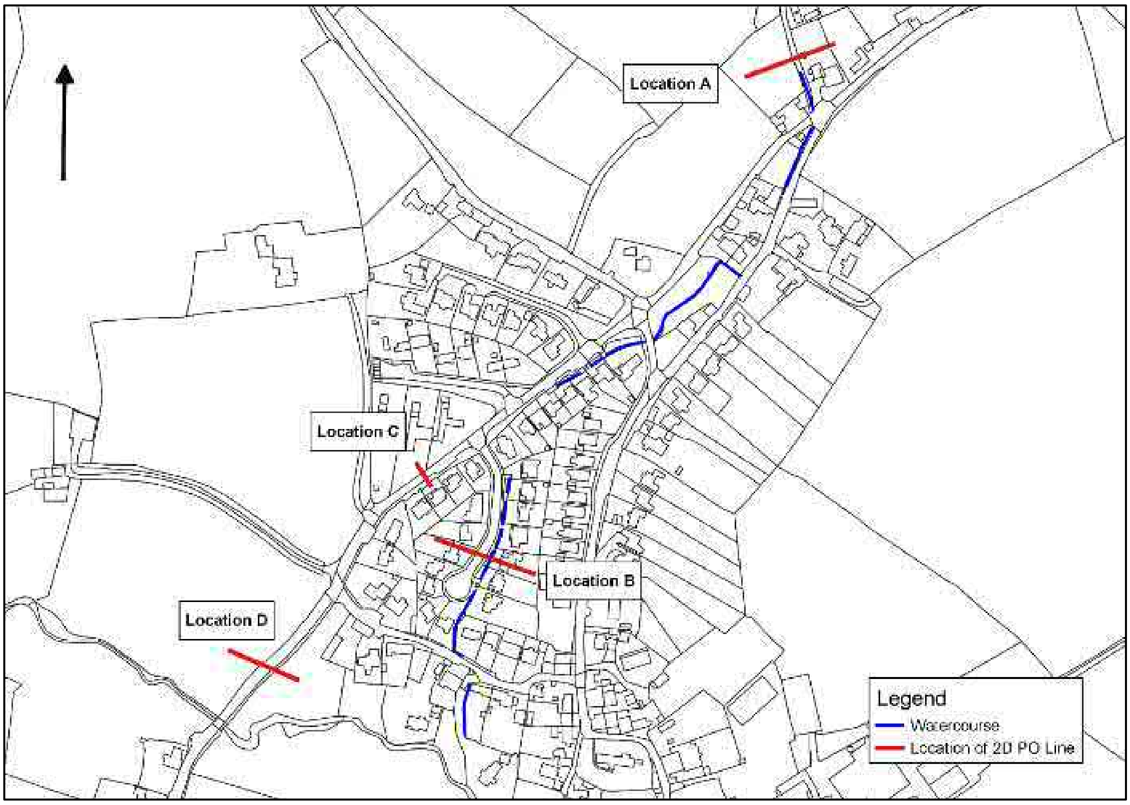

Figure 7-2: Location of 2d_PO Line Flow Estimation Locations

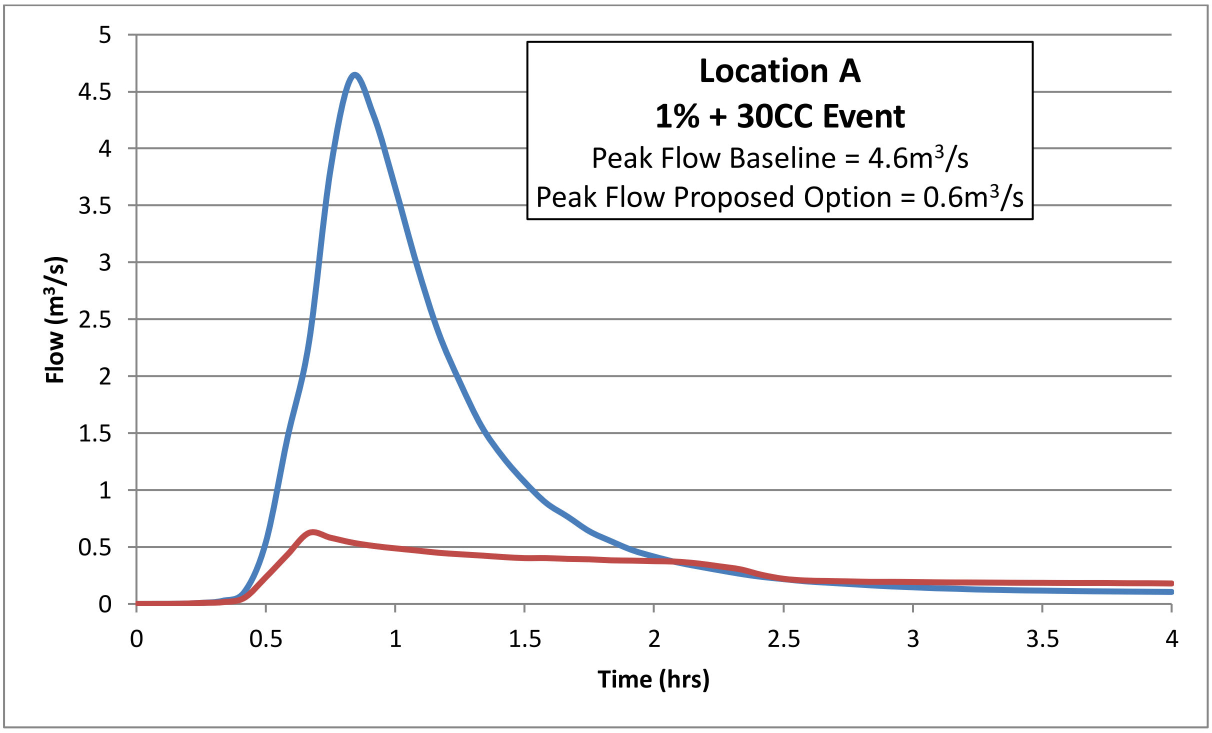

Figure 7-3 2D PO Flow, Proposed Option vs Baseline, 1% AEP + 30%CC, Upstream of Llanmaes (Location A)

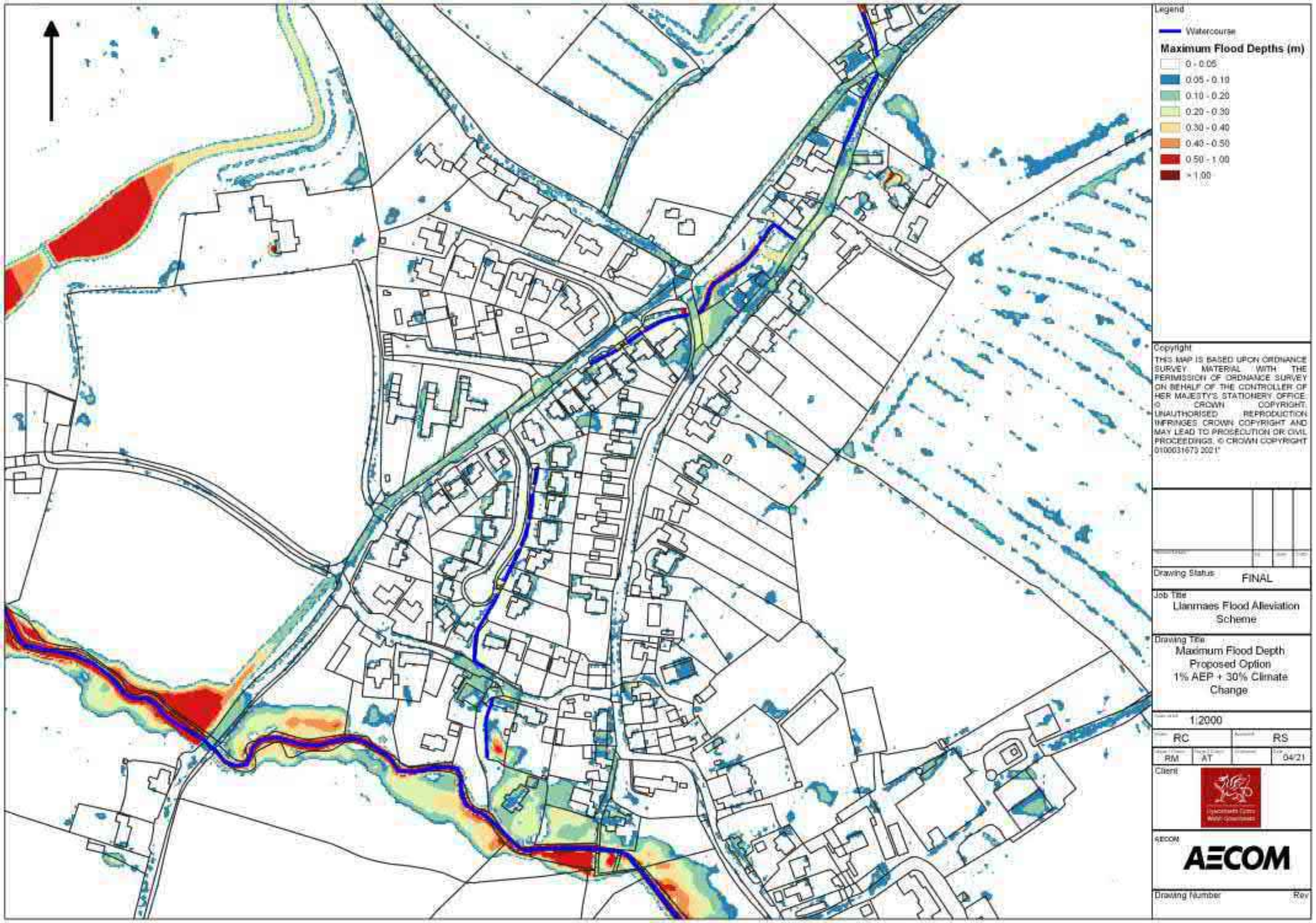

Figure 7-4: Maximum Flood Depth, Proposed Option, 1% AEP + 30% Climate Change

7.3 Attenuation Storage and Ditches

The reduced flooding within Llanmaes shown in the Proposed Option (Figure 7-1) is primarily as a result of the implementation of flood storage areas upstream of the village. The flood storage areas have been designed to attenuate flood flows up to the 1% AEP + 30% climate change scenario inclusive of at least a 0.3m freeboard in accordance with NRW guidance. Figure 7-5 shows the location of the storage areas and Table 7-2 shows the maximum storage and flood depths provided by the flood bunds.

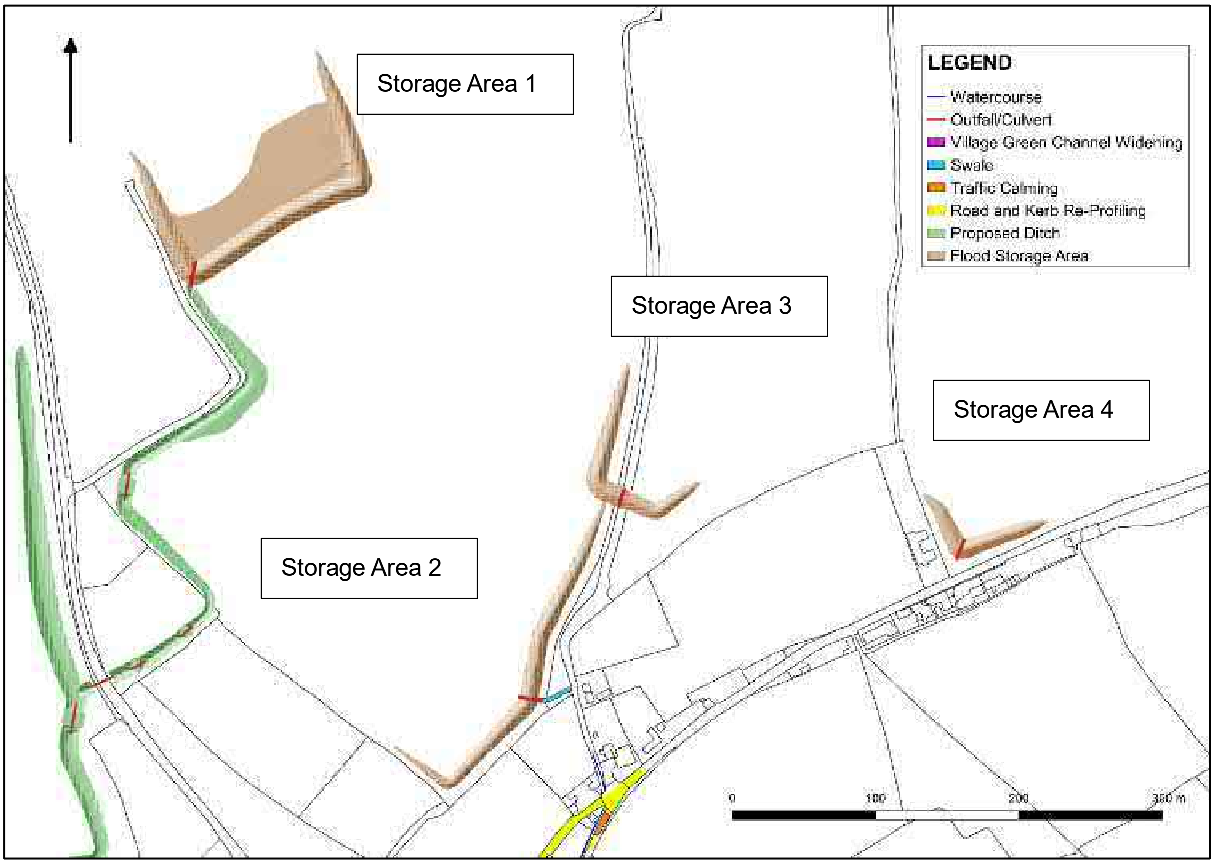

Figure 7-5: Flood Storage Area Classification

Table 7-2: Comparison of maximum storage and water depth in the proposed storage areas

Storage Area	Attribute	20% AEP	1% AEP+ 30% CC	0.1% AEP
1	Maximum Storage Volume	1100m^3	4700m^3	6700m^3
	Maximum Depth	0.60m	1.10m	1.30m
2	Maximum Storage Volume	550m^3	2600m^3	3800m^3
	Maximum Depth	0.50m	0.95m	1.05m
3	Maximum Storage Volume	300m^3	1000m^3	1400m^3
	Maximum Depth	0.60m	1.20m	1.40m
4	Maximum Storage Volume	50m^3	150m^3	200m^3
	Maximum Depth	0.25m	0.55m	0.65m

It can be seen in Table 7-2 that all storage areas are below 10,000m^3 and are therefore not considered to be reservoirs under the Reservoir Act[25] (1975). A sensitivity simulation has been carried out on the potential blockage of all storage areas and is described further within Section 7.5.

Additional flood storage is provided by two check dams within Ditch 1 which discharge through 300mm pipes. Table 7-3 shows the surface water stored within the Ditch 1 during the 20%, 1% + 30% climate change and 0.1% AEP events. It can be seen that a maximum of approximately 4650m^3 is stored in Ditch 1 in the 0.1% AEP but is also effective at storing water during lower order magnitude events too. Flood storage within the ditches is stored below the surrounding ground level.

Table 7-3: Flood Storage within Ditch 1

Annual Exceedance Probability (AEP)	Flood Storage within North Ditch
20%	1900m^3
1% + 30%CC	4050m^3
0.1%	4650m^3

7.4 Downstream Impacts

It is a requirement of TAN15 that there is no increase in flooding elsewhere as a consequence of the Proposed Development. An assessment was therefore carried out on the post development flow hydrographs on Llanmaes Brook and Boverton Brook downstream of the Llanmaes FAS to understand if the scheme had any detrimental impact downstream (Section 6.4 and Section 7.4 of Appendix C).

Figure 7-6 shows a comparison of the Baseline and Proposed flow hydrograph on Llanmaes Brook upstream of the NAR for the 1% AEP + 30% climate change event. It can be seen that there is a reduction in peak flow on Llanmaes Brook from 12.0m^3/s to 10.0m^3/s as a consequence of the Llanmaes FAS. Furthermore, there is a significant reduction in the volume of pass on flow due to the attenuation of surface water in the upper catchment.

[25] HMSO 1975, The Reservoirs Act 1975

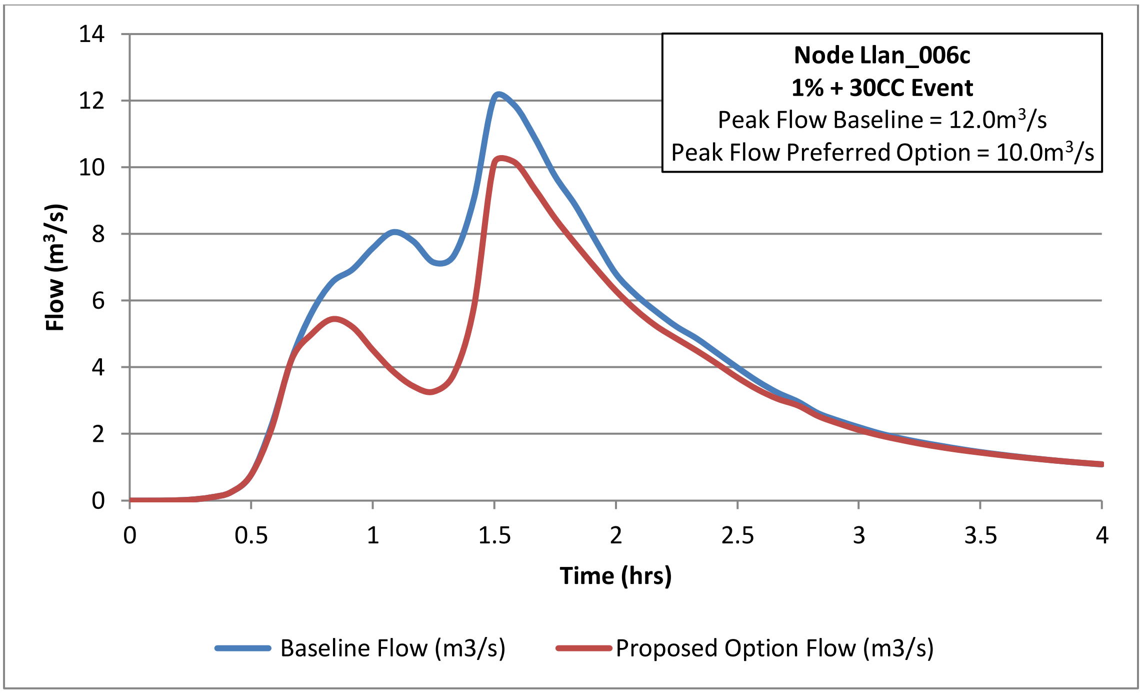

Figure 7-6: Flow Comparison Upstream of NAR, 1% AEP + 30%CC (Node Llan006c)

Peak flows on Llanmaes Brook were extracted from the hydraulic model on Llanmaes Brook upstream of the NAR and are shown in Table 7-4. It can be seen that across the range of design events from 20% AEP to 0.1% AEP there is a reduction in the peak flow on Llanmaes Brook as a consequence of the scheme.

Table 7-4: Peak Flow Comparison Upstream of NAR (Node Llan006c)

AEP	Baseline	Proposed Option	Difference
20%	1.6m^3/s	1.1m^3/s	-0.5m^3/s
1% + 30% CC	12.1m^3/s	10.2m^3/s	-1.9m^3/s
0.1%	23.1m^3/s	18.8m^3/s	-4.3m^3/s

To assess the impacts to flows on Boverton Brook, the pluvial hydraulic model rainfall catchment was extended to include the Boverton Brook catchment and simulated for the 1% AEP + 30% climate change AEP event (Section 7.4 of Appendix C). Flow hydrographs were then compared between the Proposed Option and Baseline scenarios at a location immediately downstream of the Boverton Brook railway crossing. Figure 7-7 indicates that there is a reduction in the flow hydrograph as a result of the Proposed Option downstream of the railway culvert when compared to the Baseline scenario for the 1% AEP + 30% climate change event. Model results show that there are no detrimental impact to flows on Boverton Brook (Table 7-5).

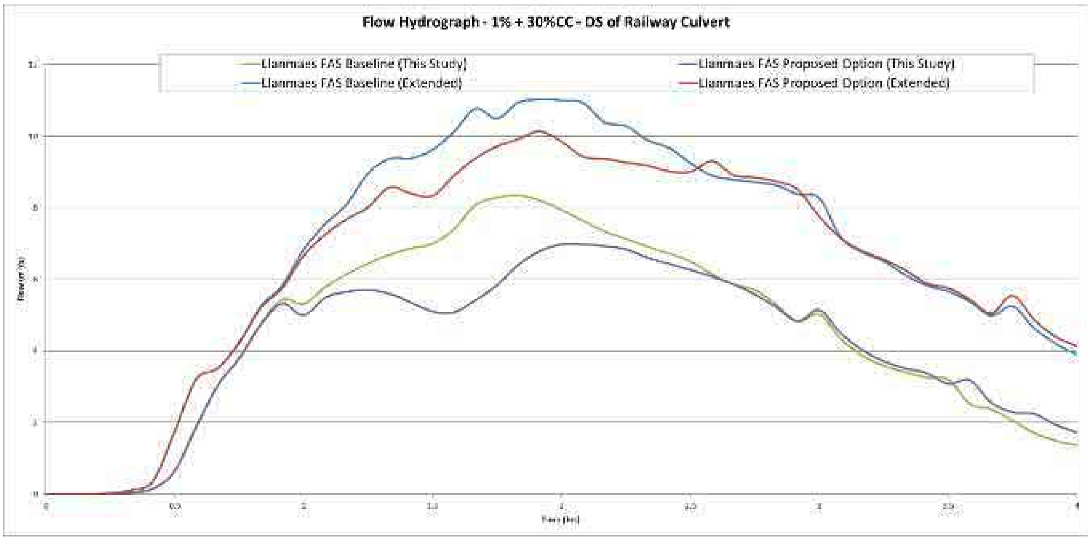

Figure 7-7: Sensitivity Flow Comparison Downstream of Boverton Brook Railway Culvert 1% AEP + 30%CC (Node Bov_042b)

Table 7-5: Peak Flow Comparison at Boverton Brook Railway Culvert (Node Bov_042b)

AEP	Baseline	Proposed Option	Difference
1% + 30% CC	11.0 m^3/s	10.1 m^3/s	-0.9 m^3/s

7.5 Exceedance and Blockage

It is a requirement of TAN 15 to demonstrate that the Proposed Development does not increase flooding elsewhere up to and including the 0.1% AEP event. Figure 7-8 and Figure 7-9 show the depth difference plot for the 1% AEP + 75% climate change and 0.1% AEP respectively comparing the Proposed Option and Baseline maximum flood depths. It can be seen that there is a general reduction in flood depths throughout Llanmaes (0.1m-0.2m) whilst there is a subsequent increase in flood depths at the storage areas, Village Green, West Road and within the outfall ditches as intended when compared to the baseline. There is a residual increase in flood depths on Llanmaes Brook upstream of the West Road bridge of +0.03m similarly described in Section 7.2.1 and is discussed further in Section 8.3. It has been demonstrated that there is no detrimental effect on flood risk downstream of Llanmaes. As such, it can be concluded the scheme is effective even during extreme events.

Blockage of the attenuation area outfall is possible given the location within agricultural fields and therefore a sensitivity test was undertaken to assess the impacts of such a blockage on the functionality of the storage areas in line with NRW's OGN100[26]. A worse case blockage scenario (100% blockage) was carried out on all storage area outfalls for the 0.1% AEP event (Appendix C). The results show that the volume of water held back is below 10,000m^3 and is therefore below the definition of a reservoir according to the Reservoir Act (1975). All water is attenuated in the flood storage areas except at Bund 4 where the model results show that there is minor bypassing of the bund leading to increased flooding of +0.01m to +0.05m to the west when compared to the Baseline. It has been demonstrated that the flood storage areas are effective for all design events and the configuration of the bunds will be reviewed prior to construction to improve efficiency where possible and remove this residual risk whilst maintaining the conclusions of this FCA. A full description of the analysis is found in Appendix C.

[26] NRW 2015 Flood Risk Management: Modelling blockage and breach scenarios. OGN100

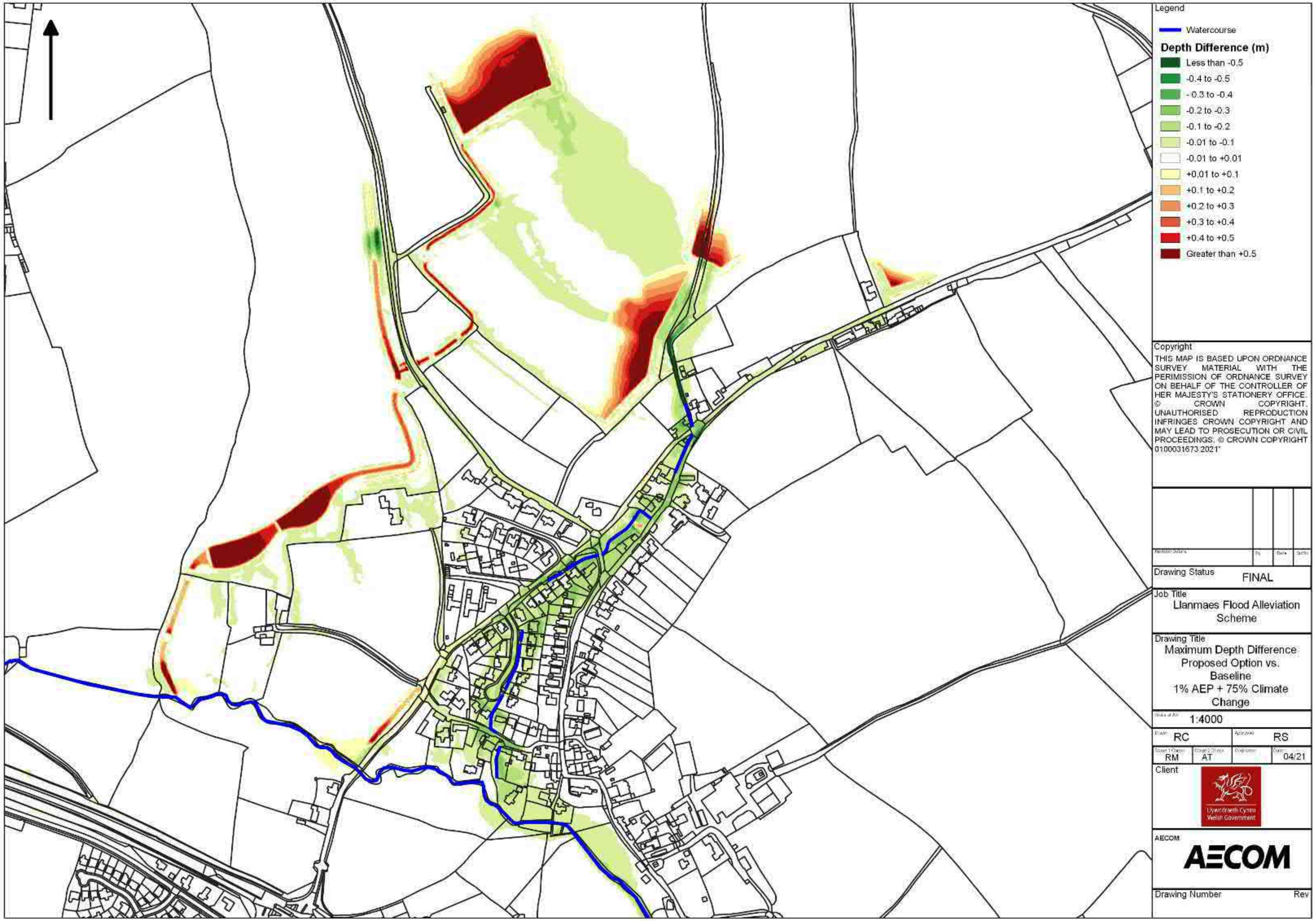

Figure 7-8: Depth Difference Map, Proposed Option vs. Baseline, 1% AEP + 75% Climate Change

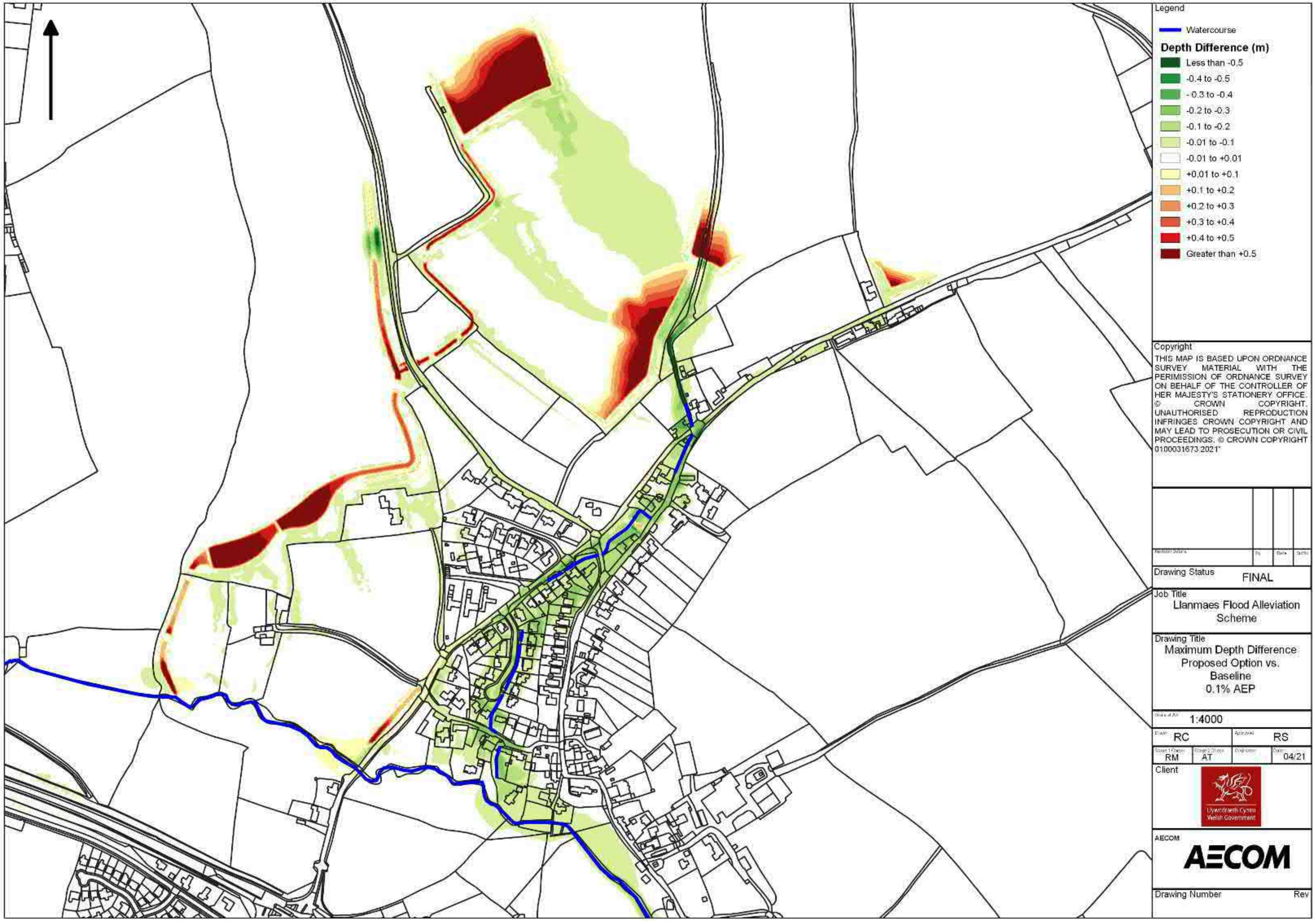

Figure 7-9: Depth Difference Map, Proposed Option vs. Baseline, 0.1% AEP

8. Mitigation Measures and Residual Flood Risk

It has been demonstrated that the Proposed Option provides a significant reduction in the overall flood depths throughout Llanmaes across all simulated AEP events (Section 7.2). However, due to the volume of water entering Llanmaes and limited capacity of the unnamed tributary channel, the results show that all flood risk could not be mitigated against for some properties, although this is not exacerbated by the introduction of the Proposed Scheme. To reduce the residual flood risk through Llanmaes, a number of additional mitigation measures were included in the Proposed Option design:

- Ensure all road re-profiling falls away from properties at risk of flooding;
- Raised tables at all West Road junctions were designed to ensure no water escapes the reprofiled West Road;
- All attenuation storage areas have a 0.3m diameter overflow pipe at a level 1.3m above the primary outfall invert level to provide a controlled outlet in the event of blockage;
- Check dams within the ditch configuration to increase upstream storage;
- Safety in Design Risk Assessment (Appendix D);
- Discussions with landowners being undertaken, informed by this FCA
- Improved highway drainage along West Road and Sigingstone Lane (Section 9); and
- Recommendation of Property Level Resilience measures for properties unable to be removed from flooding.

This section outlines the residual flood risk within Llanmaes following the implementation of the Proposed Option.

8.1 Properties at Risk of Flooding

In order to understand the benefits of the scheme, the numbers of properties which experience internal flooding within the Baseline model are compared against the Proposed Option model for all AEP's. The identification method of flooded properties is the same as that specified in Section 6.3.2. Table 8-1 shows the number of properties affected by flooding in the Proposed Option scenario compared to the Baseline scenario.

Table 8-1: Comparison of Properties Affected By Flooding - Baseline and Proposed Option Model

AEP	Baseline - Affected Properties	Proposed Option Affected Properties	Inundated Properties Reduction (Complete Removal)
20%	19	14	-5 (-26%)
10%	27	16	-11 (-41%)
5%	31	17	-14 (-45%)
2%	45	21	-24 (-53%)
1% + 30% CC	61	26	-35 (-57%)

It can be seen that there is a reduction in the number of properties that are estimated to flood across all design events. This is most pronounced during the 1% AEP + 30% climate change event where 35 properties are completely removed from inundation in comparison to the Baseline scenario.

8.2 Flood Hazard

The Proposed Option is fundamentally reliant upon the creation of upstream flood storage areas and the formalisation of an overland flow route within the highway through the village to function efficiently. The Proposed Option has been shown to provide significant benefit to the level of flood risk within residential property footprints throughout Llanmaes. However, there is an associated increase in flood depths where these mitigation measures have been proposed which may create residual flood risk.

To understand how the Proposed Option has changed the risk posed to members of the public, Flood Hazard Maps have been created for the Baseline and Proposed Option model results (Appendix C). The Flood Hazard Rating used within this report is based upon the October 2005, Defra/EA produced 'Flood Risk Assessment Guidance for New Development (Phase 2)[27].

Model results show that there has been a decrease in the flood hazard rating throughout Llanmaes as a result of the Proposed Option. However, it can be seen that areas of intended storage (upstream attenuation storage, ditches, Village Green) have increased to become 'danger to most'. As such, to further reduce the residual flood risk a safety in design risk assessment has been undertaken to ensure the public are aware of areas that pose a residual flood hazard (Appendix D).

8.3 Impact to Agricultural Fields

It has been highlighted in Section 7.2 that model results indicate there is a small increase in the maximum flood depths within the agricultural fields between the Ditch 1 outfall and Tara House for all events of larger magnitude than the 20% AEP event. This is a consequence of the formalisation of overland flow routes along the Ditch 1 and along West Road.

Whilst there is an increase in flood depths within the agricultural fields along Llanmaes Brook there is no increase in the overall flood extent as a result of the increased flood depths. That is to say that these areas already experience significant flooding during the events larger than the 20% AEP event. This is demonstrated in Figure 8-1 and Table 8-2 which shows the extraction location of maximum flood depths compared to the Baseline scenario.

Figure 8-1 also shows the 0.1% AEP flood extent with a depth greater than 0.05m with the areas of increased flood depths greater than 0.02m demonstrating all detrimental effects are within the floodplain. Table 8-2 shows that for all flood events, the magnitude of the increase is small compared to the existing baseline conditions along the Llanmaes Brook floodplain (Locations 1 to 4). The greatest increase in flood depths is at the Ditch 3 outfall where there is an increase of up to +0.02m within the agricultural fields. It is recognised that all areas of increased flood depths are on private land. VoGC have commenced discussions with land owners through presentation of initial hydraulic modelling results presented within this FCA and preliminary agreements have been made to facilitate the scheme. These discussions are ongoing and VoGC aims to formalise these agreements prior construction works commence.

[27] Defra/Environment Agency, 2005 'Flood Risk Assessment Guidance for New Development (Phase 2)', FD2320/TR2. Available from: http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2320_3364_TRP_pdf.sflb.ashx.

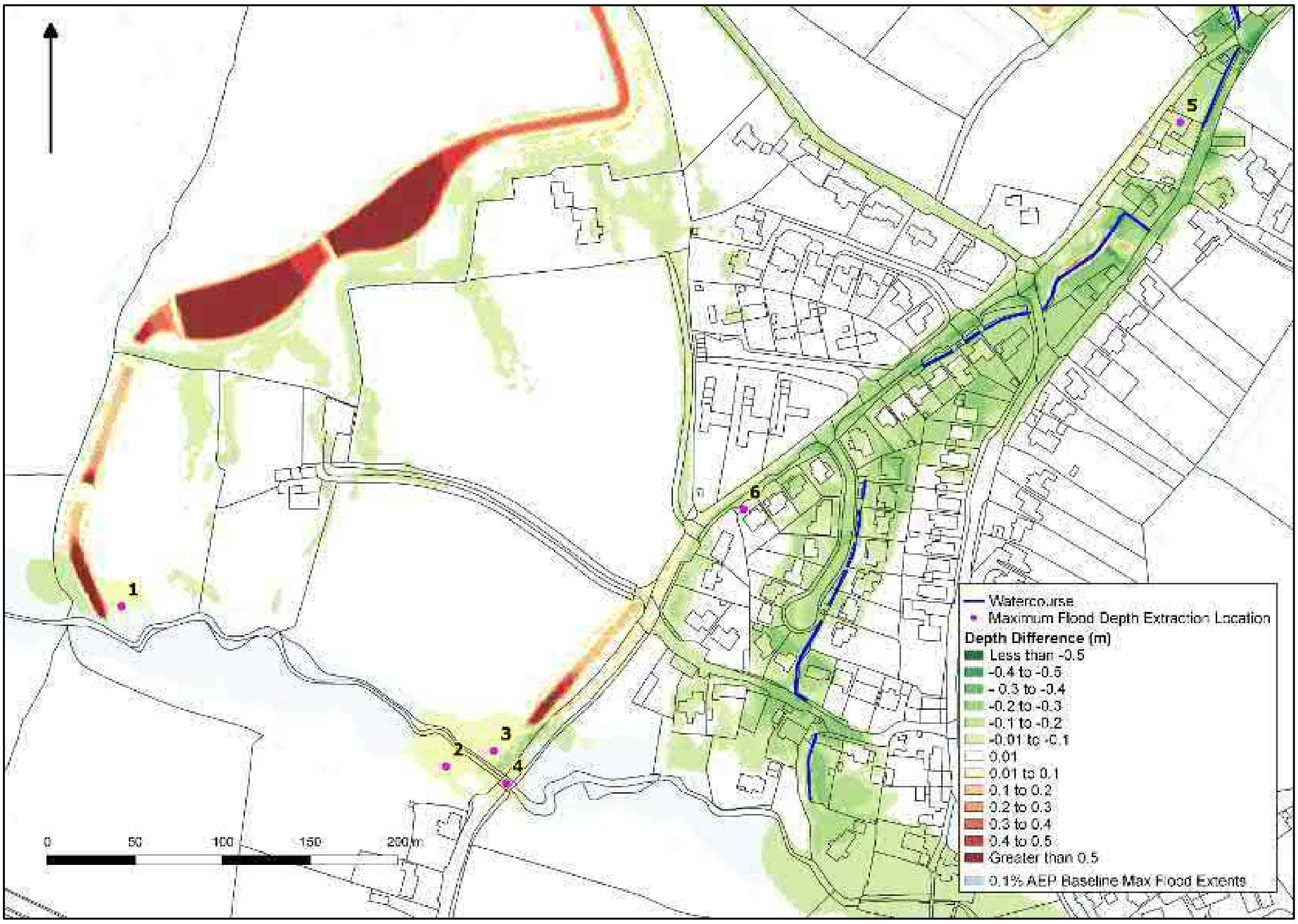

Figure 8-1: Location of Detriment on Llanmaes Brook Compared to Baseline Scenario (0.1% AEP) With Location of Maximum Flood Depth Extraction Points

Table 8-2: Maximum Flood Depth Comparison Proposed Option vs Baseline

Scenario	Flood Data Extraction Point					
	1	2	3	4	5	6
20% AEP Baseline	0.01	0.01	0.00	0.02	0.02	0.02
20% AEP Detailed Design	0.01	0.01	0.02	0.02	0.05	0.04
Depth Difference	0.00	0.00	+0.02	0.00	+0.03	+0.02
1% AEP+30%CC Baseline	0.10	0.22	0.63	0.10	0.11	0.11
1% AEP+30%CC Detailed Design	0.11	0.25	0.65	0.11	0.08	0.13
Depth Difference	+0.02	+0.02	+0.03	+0.02	-0.03	+0.02
0.1% AEP Baseline	0.25	0.39	0.78	0.23	0.17	0.15
0.1% AEP Detailed Design	0.26	0.41	0.80	0.25	0.09	0.15
Depth Difference	+0.01	+0.02	+0.02	+0.02	-0.08	0.00

It has been demonstrated throughout this report that the Proposed Llanmaes FAS has a positive reduction in flood depths to sensitive receptors through Llanmaes (Sections 7.2) and an overall reduction in the flow hydrograph downstream of the village (Section 7.4) for all the design events. This reduction is primarily the result of the implementation of the attenuation storage areas to the north of the village. However, the scheme also relies on the formalisation of two flow paths which outfall into Llanmaes Brook in order to reduce the overall volume conveyed by the existing flow path through the village (Figure 6-2). These interventions consist of the Ditch 1 and Ditch 2 arrangement that intercepts overland flow from the north of Llanmaes and the road re-profiling of West Road that maintains a flow path through Llanmaes within the highway to protect properties from flooding.

A consequence of these two new outfalls is that for an approximate 500m reach of Llanmaes Brook from the Ditch 1 outfall to the existing outfall of the unnamed tributary there is an increase in the peak flows on Llanmaes Brook which results in the increase in flood depths in agricultural fields described above. Table 8-3 shows a comparison of the peak flow on Llanmaes Brook between the Proposed Option and Baseline scenario. It can be seen that during the 1% AEP + 30% climate change event there is an increase in peak flow between the North Ditch outfall and upstream of Tara House of 0.1m^3/s. It has been demonstrated in Section 7.4 that there is an overall reduction in the volumes and peak flows downstream of Llanmaes and therefore this means the increase in flows on Llanmaes Brook between the outfalls represents a redirection of flood risk away from properties to an area of lower risk. The justification for this is as follows:

- The hydraulic model does not consider infiltration into the ditch which is a conservative approach. It is likely that some water would be lost to the ground and the outfall would be less than currently observed;
- There is no increase in flood extents from the Baseline results and all observed increased flood depths are contained within the baseline floodplain (existing);
- There is no change in flood risk to significant receptors and all increases to flood depths are within agricultural fields; and
- The pass-on peak flow and total volume has been reduced from Llanmaes Brook (Section 7.4) which should have a positive influence on the effectiveness of the standard of protection afforded by downstream receptors.

Table 8-3: Comparison of Peak Flows on Llanmaes Brook Between North Ditch Outfall and Upstream of Tara House, 1% AEP + 30% Climate Change

Node		Baseline Peak Flow	Proposed Option Peak Flow
Upstream of West Road Bridge (016a)	20% AEP	0.3m^3/s	0.3 m^3/s
	2% AEP	2.6 m^3/s	2.6 m^3/s
	1% AEP + 30%CC	9.3 m^3/s	9.4 m^3/s
West Road Bridge	20% AEP	0.4 m^3/s	0.5 m^3/s
	2% AEP	2.6 m^3/s	2.6 m^3/s
	1% AEP + 30%CC	9.1 m^3/s	9.2 m^3/s
Upstream of Tara House (013a)	20% AEP	0.5 m^3/s	0.6 m^3/s
	2% AEP	2.6 m^3/s	2.6 m^3/s
	1% AEP + 30%CC	9.2 m^3/s	9.2 m^3/s

Based on this assessment, it is recommended that VoGC liaise with the relevant landowners to ensure that this part of the FAS can function as intended. A change in the flow regime of Llanmaes Brook for this length of Main River may require a Flood Risk Activity Permit agreement with NRW.

8.4 Model Uncertainty

Sensitivity testing is undertaken on all hydraulic models in order to document how the relationship of model outputs can be apportioned to different sources of model parameter variance. Sensitivity simulations have been undertaken to increase the confidence in the hydraulic model results. Full details of the sensitivity analysis undertaken can be found in Appendix C. At the request of NRW, sensitivity analysis was undertaken on the percentage runoff within the catchment.

It was found that whilst the hydraulic model is sensitive to changes in roughness characteristics of the catchment and the percentage runoff in the catchment, the Proposed Option continues to function to reduce flood depths within Llanmaes whilst at the same time reducing the pass on flow to Llanmaes Brook and ultimately downstream.

8.5 Maintenance and Ownership

To ensure the functioning of the Proposed Option VoGC will be responsible ongoing maintaining, inspections and ownership of these assets. VoGC may wish to form maintenance agreements with land owners for all assets located within private land. All other public road related interventions (road drainage systems etc) will be subjected to VoGC existing maintenance regime.

9. Highway Surface Water Management

9.1 Sigingstone Lane

9.1.1 Existing

Runoff from the road is currently directed towards the verge (Figure 9-1). There are limited formal drainage features along this section of local road and the runoff, where possible, discharges to ditches that run parallel to the road. During storm events the runoff cannot infiltrate into the verge effectively and runs along the road from north to south into the village. The baseline modelling scenario identified significant depth of flow along this pathway into the village, this is in line with site observations.

Figure 9-1: Existing Sigingstone Lane, @photo from AECOM site visit

9.1.2 Proposed

The proposals will reprofile the existing lane to provide standard crossfalls which will direct runoff effectively into a new filter drain located in the western verge (Figure 9-2). The runoff will drain 'over the edge' into the filter drain where it will be collected and discharged to the new ditch located beyond the hedge line. This helps remove surface water flows from the lane thus minimising any runoff from the lane into the Village during a storm event.

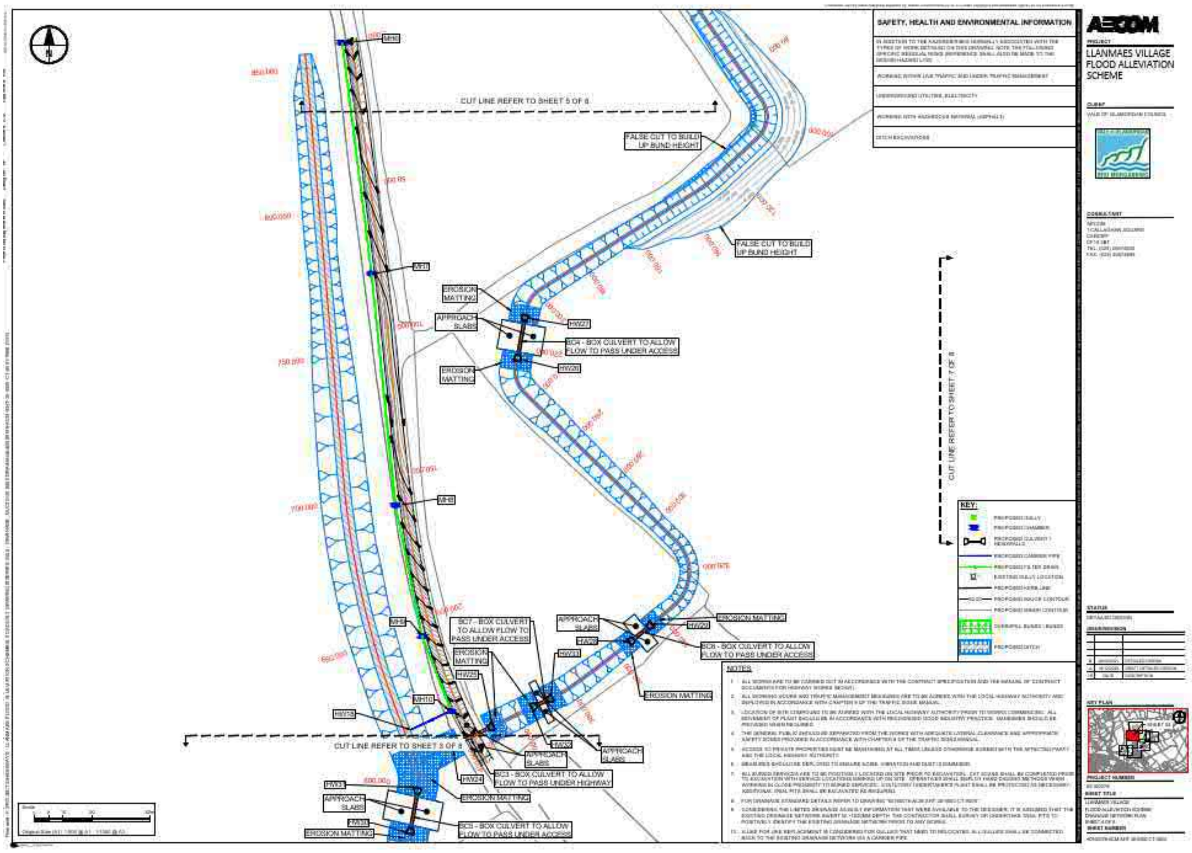

Figure 9-2: Extract from Detailed Design drawings Illustrating Proposed Drainage at Sigingstone Lane

9.2 West Road

9.2.1 Existing

At the north of the village there are existing gullies which collect and discharge a portion of the runoff (Figure 9-3). Moving south and past the village green, a formal surface water sewer is located in the carriageway which is connected to existing gullies which again capture a portion of the runoff.

Figure 9-3: Existing West Road Drainage @photograph from AECOM site visit

9.2.2 Proposed

At the north of the village the carriageway will be reprofiled and raised to channel the runoff away from properties (Figure 9-4). New gullies are provided which will help to drain the runoff and existing gullies are repositioned to align with the new road alignment.

From the Village Green southwards, a new surface water carrier drain is proposed to increase capacity of the road drainage system. Increased numbers of gullies will also be provided to improve the collection of runoff from the road surface. This new sewer will discharge flows into the new ditch located to the west of the road. This ditch will attenuate and treat the runoff prior to discharge to Llanmaes brook.

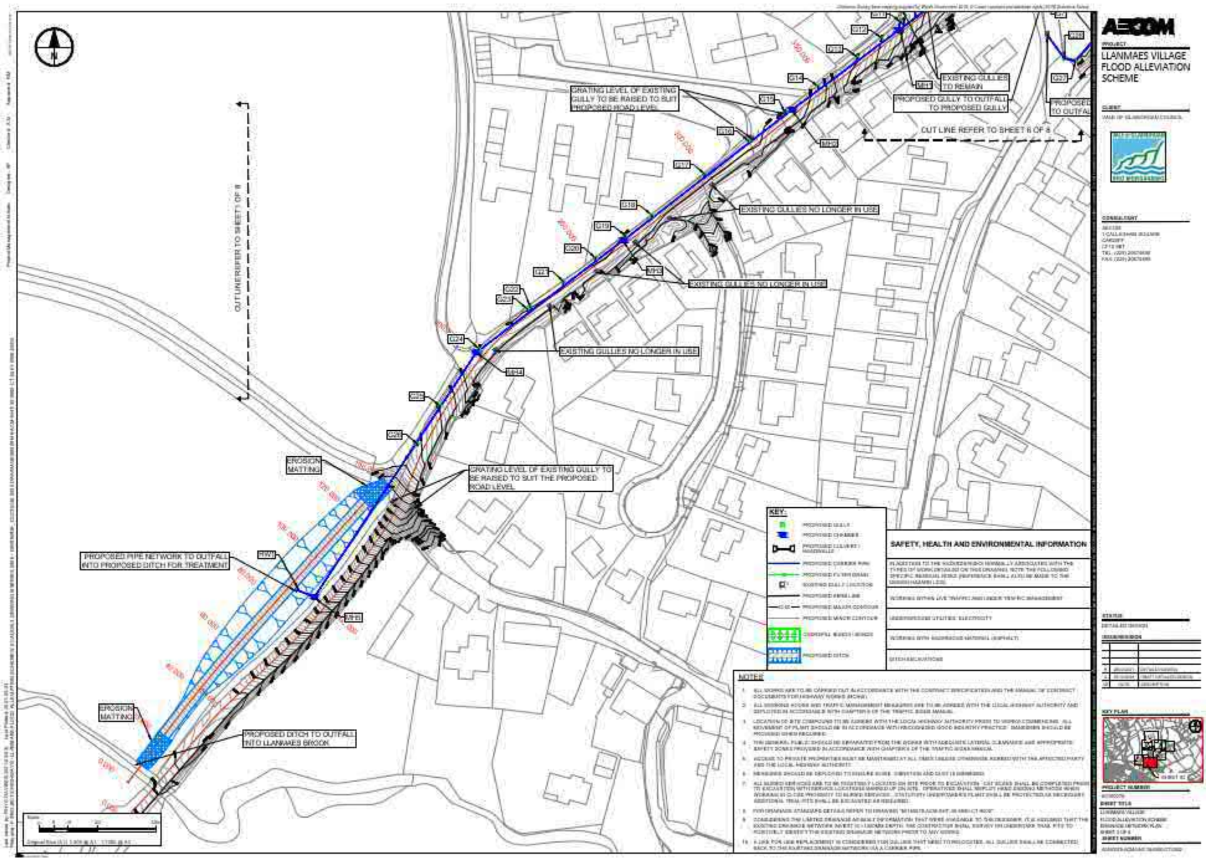

Figure 9-4: Road Reprofiling with New Gullies and Carrier Pipe Discharging to Ditch 3

9.3 West Road Junction with Village Green Road

9.3.1 Existing

Adjacent to the Village Green there are existing gullies that currently outfall towards the Village Green and that also have a record of historical blockages (Figure 9-5).

9.3.2 Proposed

At the north of Village Green road there are existing gullies which collect and discharge runoff (Figure 9-6). Moving south and past The Croft, gullies with blockages and capacity issues are located in both sides of the road. The proposed drainage will see this network being extended and redirected to discharge into the existing drainage network at the west end of the Village Green which ultimately outfalls into the unnamed tributary..

Figure 9-5:Existing Drainage, @photograph from AECOM site visit

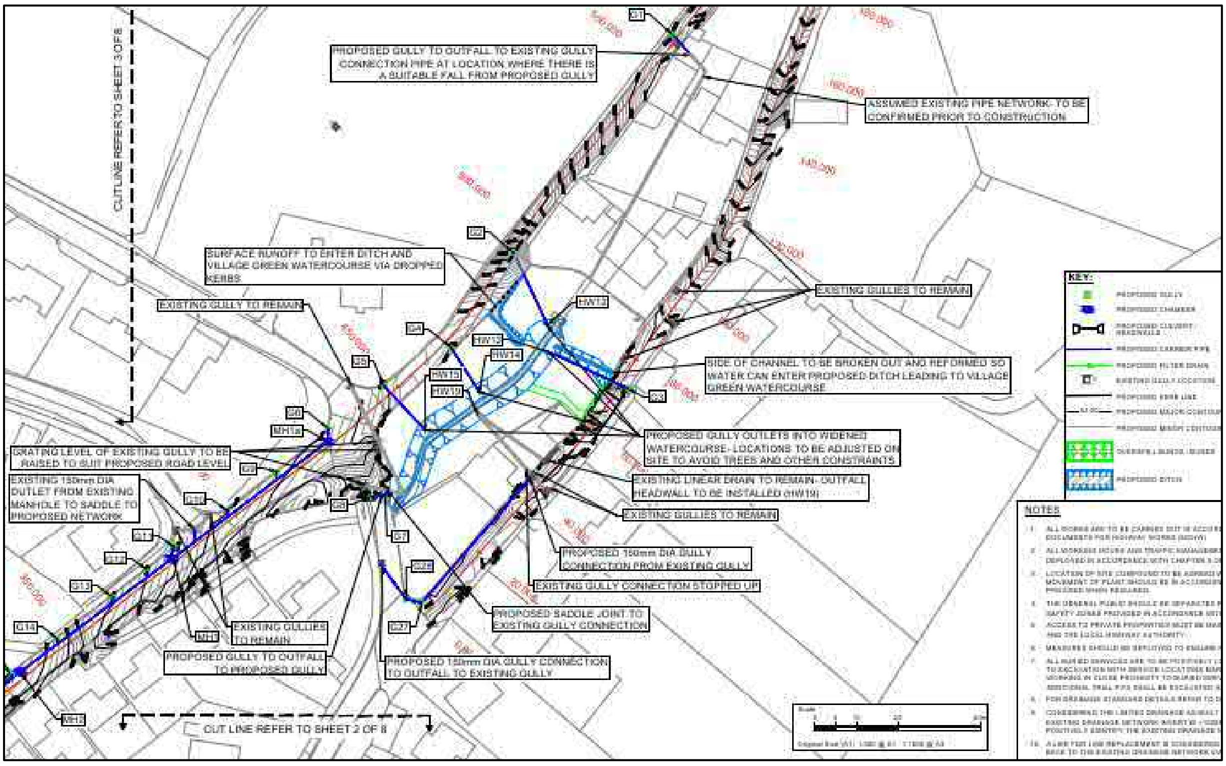

Figure 9-6: Proposed Design, Village Green/West Road

9.4 Additional Resilience

The road drainage system, including the gullies and carrier pipe have not been taken into consideration in the flood modelling simulations. With the inclusion of the new road drainage system there will be increased flood resilience beyond that shown in the modelling, with the road drainage system collecting and safely discharging a portion of the surface flows.

10. Conclusion

As a FAS, the development is designed to reduce the existing flood risk to Llanmaes. This FCA has therefore assessed the flood risk, in accordance with TAN15, to and from the proposed Llanmaes FAS compared to the existing levels of flood risk to Llanmaes. It is apparent from anecdotal evidence that surface water flooding poses the largest flood risk to the village and therefore pluvial hydraulic modelling was agreed with NRW to provide the most robust assessment of flood risk for the catchment.

The initial assessment of flood risk to Llanmaes, prior to hydraulic modelling is:

- Surface water - High risk
- Fluvial - High risk
- Sewer flooding - Medium risk
- Groundwater - Low risk
- Artificial Sources - No risk
- Tidal - No risk

A Baseline pluvial hydraulic model was created using the 2016 NAR FCA model to assess the existing surface water flood risk to Llanmaes. Model results corroborate anecdotal evidence of the key mechanisms of flooding through Llanmaes, namely that a series of overland flow paths contribute to flooding within Llanmaes where the watercourse and culvert network is not capable of conveying such high flows. Flooding is prevalent around the Village Green and Low Road in all simulated baseline events.

The Proposed Option is a combination of upstream storage, ditches and highway improvements. The hydraulic model results show that there is a significant decrease in maximum flood depths within Llanmaes across all simulated events as a result of the proposed Llanmaes FAS. Due to the volume of water entering Llanmaes from many discreet locations, in conjunction with the limited capacity of the existing watercourse, it was not possible to completely eliminate flooding within the village to the design event standard. During the 1% AEP + 30% climate change event, the Proposed Option produces a reduction of properties affected by flooding from 61 to 26. Those properties which could not be completely removed from the flood extents have been identified as those which may be managed through the implementation of targeted Property Level Resilience measures.

To reduce the residual flood risk through the village, a number of additional mitigation measures were included in Proposed Option design:

- Ensure all road re-profiling falls away from properties at risk of flooding;
- Flood relief culverts at attenuation area outfalls to reduce risk of blockage;
- Check dams within Ditch 1 to increase storage and reduce the flow rate into Llanmaes Brook;
- Permissions from landowners being sought as part of FCA; and
- Recommendation of Property Level Resilience measures for properties unable to be removed from flooding

The Proposed Option has been proven through this assessment to reduce the level of flooding through Llanmaes and provide no increase to flood risk downstream through controlling the overland flow route of water in and around Llanmaes. As a consequence of formalising two overland flow paths, hydraulic modelling results show that there is a small increase in the depths of flooding within the Llanmaes Brook floodplain for a 500m reach of Llanmaes Brook upstream of Tara House. The increase in flood depths within the Llanmaes Brook floodplain is in conflict to the requirement of TAN15, however the justification for this is as follows:

- The hydraulic model does not consider infiltration into the ditch which is a conservative approach. It is likely that some water would be lost to the ground and the outfall would be less than currently observed;
- There is no increase in flood extents from the Baseline results and all observed increased flood depths are contained within the baseline floodplain (existing);

- There is no change in flood risk to significant receptors and all increases to flood depths are within agricultural fields (intended receptor) except for two locations in Llanmaes where the model indicates increased flood depths of up to +0.02m. These have been investigated and are a consequence of the hydraulic modelling limitations whereby low level walls are not represented within the hydraulic model as described in Appendix C; and
- The pass-on peak flow and total volume has been reduced from Llanmaes Brook (Section 6.10) which should have a positive influence on the effectiveness of the standard of protection to downstream receptors.