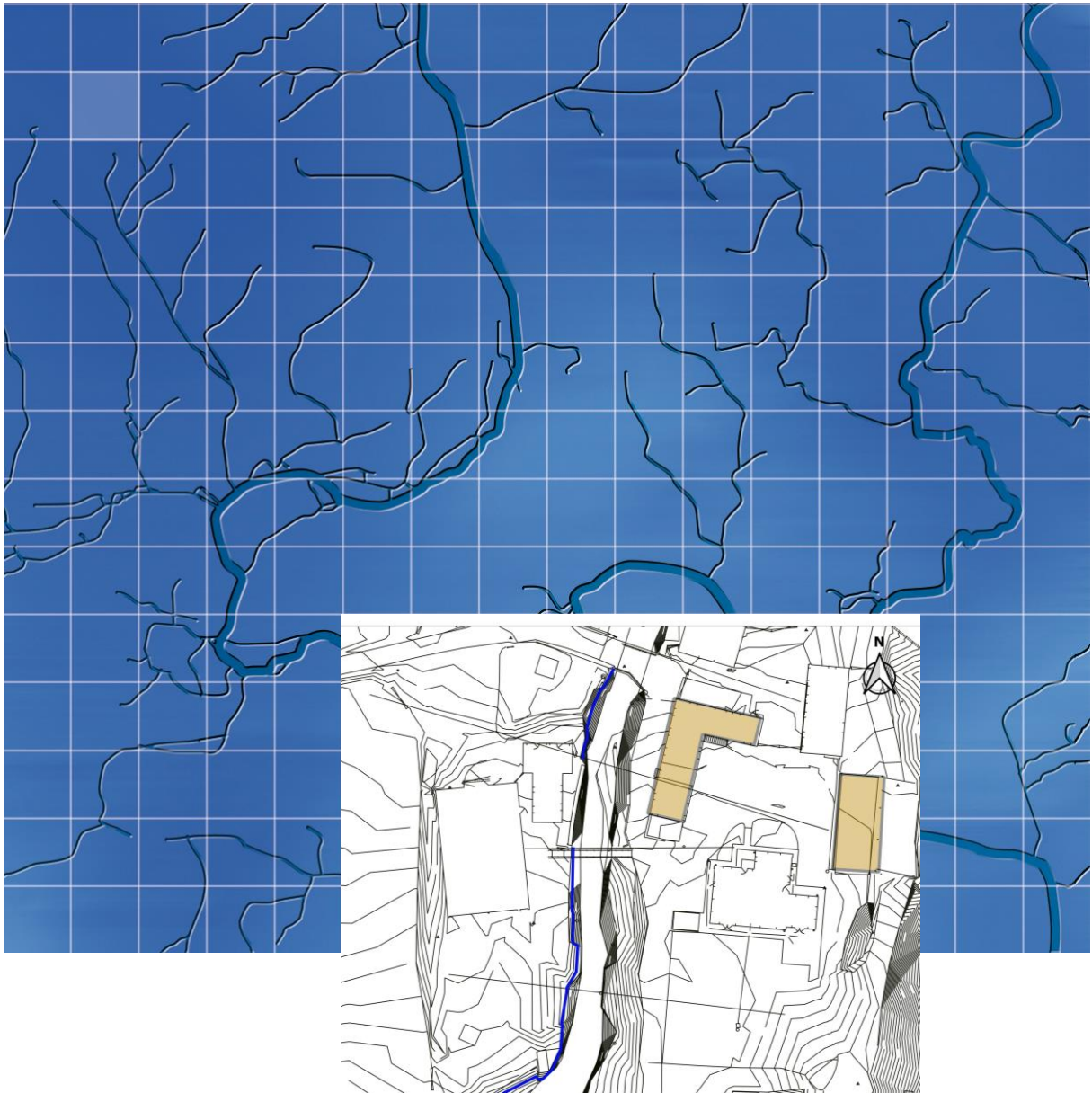


Swansea Valley Holiday Cottages

March 2019

Plas Farm Flood Consequences Assessment



Swansea Valley Holiday Cottages

Plas Farm Flood Consequences Assessment

Document issue details

WHS1663

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1.1	22/03/2019	Draft	Joel Leyshon-Jones (Consultant)	Paul Blackman (Technical Director)

For and on behalf of Wallingford HydroSolutions Ltd.

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The WHS Quality & Environmental Management system is certified as meeting the requirements of ISO 9001:2015 and ISO 14001:2015 providing environmental consultancy (including monitoring and surveying), the development of hydrological software and associated training.



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1 Introduction

1.1 Background

Wallingford HydroSolutions (WHS) Ltd. has been commissioned by Swansea Valley Holiday Cottages to undertake a Flood Consequence Assessment (FCA) in accordance with Technical Advice Note (TAN 15) to support planning permission for the conversion of two farm outbuildings to holiday accommodation and tourist facilities at Plas Farm, Rhos, Swansea. This property borders the River Clydach at (NGR) 274843, 204060.

Natural Resources Wales' (NRW) online Development Advice Map (DAM) indicates that the site currently lies largely within Flood Zone C2 and is at risk of flooding during a 1% Annual Exceedance Probability (AEP) fluvial event.

A previous modelling study at the site was carried in 2012 by WHS¹, in support of a similar change of use planning application, for four farm buildings to holiday cottages at Plas Farm. This utilised a 1D model comprised of seven river sections, to indicate flood risk to the properties and inform finished floor levels. NRW have indicated that pending updates to the hydrology inputs, in principal use of a 1D model is considered acceptable to inform flood risk for these new developments.

This FCA will identify all sources of flood risk to the site and propose mitigation options to reduce risk to the development and ensure that it can remain safe for its lifetime.

In summary, this FCA will:

- Provide a comprehensive review of all publicly available flood risk data assessing the risk to the development site.
- Quantify the flood risk associated with the proposed development through presenting the results of hydraulic modelling.

1.2 Sources of Data

The sources of data used to inform this FCA include:

- Natural Resources Wales online Flood Maps and Development Advice Map².
- TAN 15³.
- Hydraulic model data produced by WHS in 2012.
- Site drawings and plans provided by the client.
- Email correspondence from NRW.

¹ WHS. 2012. WHS2051 Plas Farm FCA v1.03 Final

² Long term flood risk. Natural Resources Wales. Accessed 2017. Available at: <https://naturalresources.wales/evidence-and-data/maps/long-term-flood-risk/?lang=en>

³ Technical Advice Note 15: Development and Flood Risk. Welsh Assembly Government. 2004.

2 Site Description

2.1 Location

Plas Farm is located 2.5km east of Pontardawe, adjacent to the River Clydach (NGR 274843, 204060). The site is accessible via an access track from Church Road, which crosses the River Clydach at NGR 274843, 204060, linking properties on both banks of the watercourse. The estate has diversified in recent years, transitioning from a working dairy farm, to now include a complex of holiday cottages, following the staged conversion of farm buildings within the site to tourist facilities and accommodation.

The proposed redevelopment includes the conversion of two further farm buildings, with a total footprint of 278m², as show in Figure 1.



Figure 1 – Site layout

2.2 Topography

The topography at the site has been analysed by obtaining LiDAR data at 2m resolution (flown in December 2001). Ground levels in proximity to the site range from approximately 149 - 157mAOD. The first proposed conversion stands at approximately the same elevation as the top of banks (floor level is indicated as 149.77mAOD), with the farmyard on the eastern banks of the River Clydach surrounding this building being relatively flat. There is then a relatively sharp incline at the location of the second proposed conversion (floor level indicated as 150.4mAOD), with land rising from approximately 149.6mAOD on its western edge, to 150.4mAOD. A detailed site survey was undertaken in August 2012⁴, including both river cross sections used in a 1D model, and also contours and spot levels including levels for key structures within the Plas Farm estate.

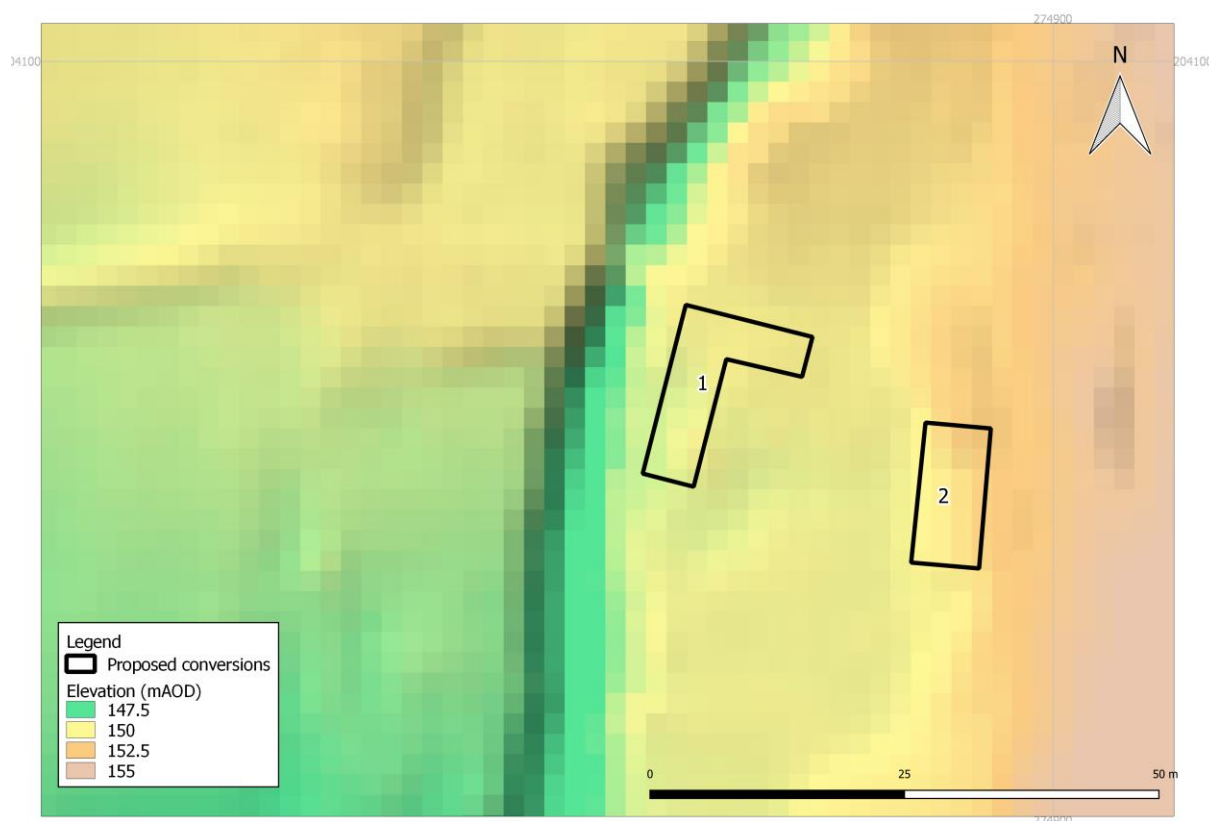


Figure 2 – Site topography as represented by 2m resolution LiDAR data

⁴ Gwalia Surveys. (2012). Plas Farm, Cilybebyll Topological Survey.

3 Flood Risk

3.1 NRW Flood Map

To initially assess the risk of fluvial flooding at the site, the NRW flood maps were reviewed. The first proposed conversion (conversion no.1), lies wholly within NRW Flood Zone 3, indicating that the annual probability of flooding is greater than 1% from fluvial sources. The second proposed conversion lies only partially within Flood Zone 2 and 3 (occupying approximately 30% of the building footprint), which *both* show the same flooding extents in this region, likely a result of the sharp ground profile at this location.

The River Clydach, running north to south at this location, has previously been modelled using J-flow software, where the river channel has not been represented in detail (being a 2D model only). This has led to a misaligning of flood extents from the main river channel, with the modelled FZ3 extent shown to be positioned some 50m west of the course of the river. The NRW flood zones are displayed in Figure 3.

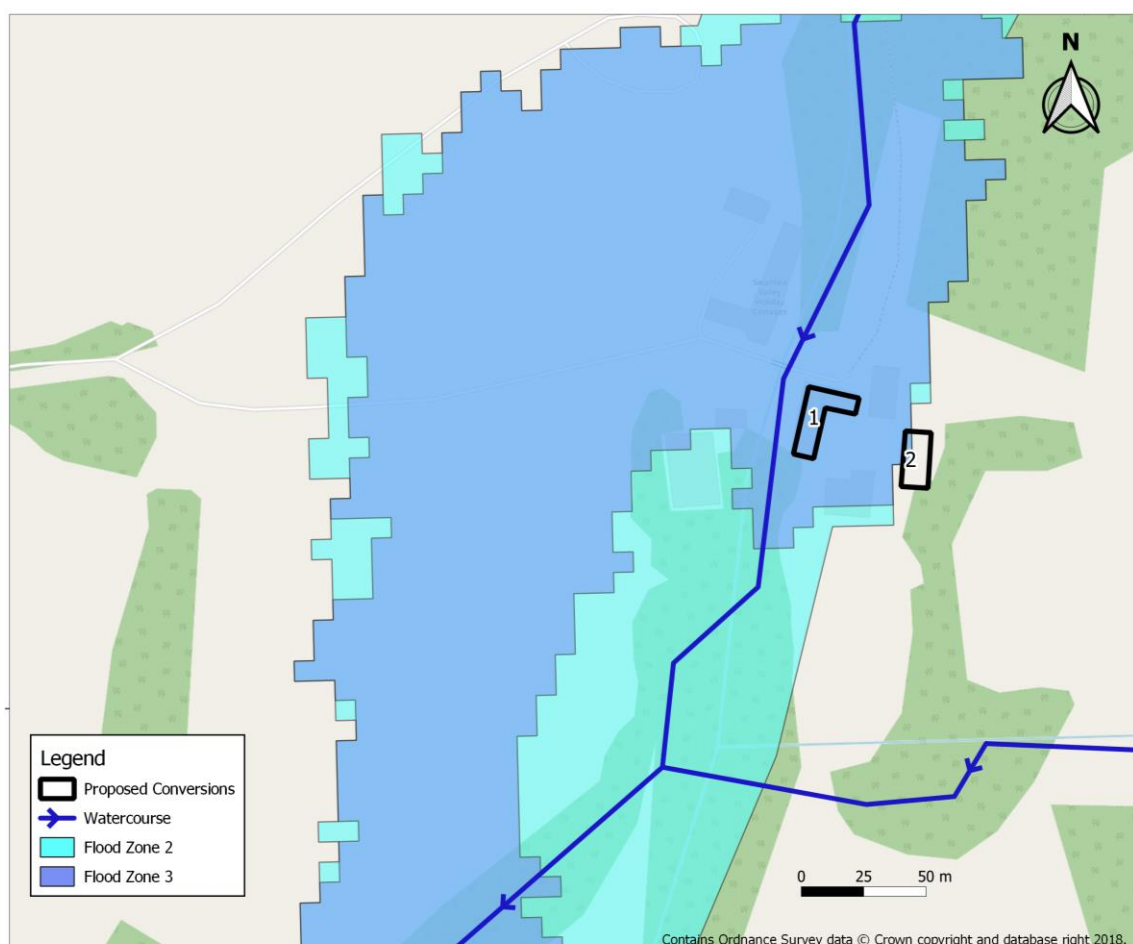


Figure 3 - NRW Fluvial Flood Zones

3.2 Modelled Flood Depths

Following communication with NRW (see Appendix 1), it was indicated that use of an existing 1D model for the River Clydach would be sufficiently detailed to inform flood risk to the proposed developments and design finished floor levels. As such, the 1D model produced by WHS in 2012 for the River Clydach was obtained and rerun using updated hydrology inputs, to represent new climate change allowances for west Wales and updated statistical peak flow datasets (see hydrology report in **Error! Reference source not found.**). The text below, details the key characteristics and assumptions of the original hydraulic model.

3.3 Hydraulic Model

A topographic survey was undertaken of the river channel and adjacent floodplain at Plas Farm by Survey Gwalia on 2nd August 2012. Seven cross sections were surveyed and were used as the basis for constructing a hydraulic model of the river using the Flood Modeller software. A site plan is included in Appendix 3 and shows the locations of the cross sections. The cross section topographical data is presented in Appendix 4. As well as capturing the location and elevation of channel, banks and floodplain, the survey also noted the surface characteristics so as to allow the selection of Manning's roughness coefficients. The bed was observed to be free of vegetation and formed of large stones. A Manning's value of 0.040 was therefore adopted for all points within the channel bed. The banks and floodplain were observed to have vegetation coverage and frequent masonry walls forming the banks and typical Manning's values adopted for these areas were in the range 0.030 – 0.035.

A road bridge crosses the river between cross sections 5 and 6. Details of the bridge structure were surveyed and included within the model. The bridge is supported by two piers rising from within the channel; one at the upstream edge of the bridge and the other at the downstream edge. The survey revealed the bridge soffit to be at an elevation of 149.553 mAOD. A footbridge crosses the river at cross section 3. The footbridge does not have any supporting structures within the river channel. The soffit of the footbridge was surveyed at 148.76 m AOD

The model was run in an unsteady state mode, using the peak flows and hydrograph derived from the flood hydrology modelling as inputs. The model was run for the 1% AEP event, the 1% AEP event adjusted for climate change (i.e. 1 in 100 year flows increased by 30%) and the 0.1% AEP event. The predicted flood levels are summarised in Table 1 **Error! Reference source not found.** The two proposed barn conversions are located on the left (east) bank. Those cross sections most pertinent to the conversions (being approximately adjacent to their locations) are shown in bold in Table 1.

Table 1 Predicted flood levels

Cross section	LB elevation (mAOD)	RB elevation (mAOD)	1% AEP flood stage (mAOD)	1% AEP + climate change flood stage (mAOD)	0.1% AEP flood stage (mAOD)
1	146.945	146.852	146.15	146.29	146.47
2	148.328	147.253	147.04	147.22	147.41
3	148.482	148.509	147.65	147.84	148.05
4	149.309	148.971	147.96	148.15	148.36
5	150.035	148.265	148.47	148.64	148.84
6	149.827	150.043	148.98	149.21	149.49
7	151.286	150.375	149.24	149.45	149.73

The runs demonstrate that the modelled river stage *does not* exceed the footbridge soffit at section 3 nor overtop the banks to interact with the footings of the bridge. This structure has not therefore not been included in the model. The runs also indicate that there is no overtopping of the road bridge at sections 5 or 6 for any event, thereby not warranting the inclusion of a spill unit at this section.

3.3.1 1% AEP + CC Flood Event

The flood model produced by WHS has been run in unsteady state for the 1% AEP event plus a 30% allowance for climate change. Where levels are shown to overtop banks, water levels extracted from the 1D model at each cross section have been plotted against contour levels at the site (as collected from the site topographic survey). Modelling results show flows for this event to be almost entirely contained by the river channel, except for overtopping downstream of the road bridge on the right bank of the River Clydach. The water levels have been projected onto contour data for the site, as shown in Figure 4. The water level at section 5 (148.64mAOD) is 1.13m below the existing floor levels of conversion no.1 (149.77mAOD) and 1.76m below existing floor levels at conversion no.2 (150.40mAOD).



Figure 4 1% AEP+CC modelled out of bank flood levels (as projected from the 1D model to site contour data)

3.3.2 0.1% AEP Flood Event

Model results for this event show banks to be overtopped at sections 2 and 6. Section 2, is 25 m downstream of the proposed development and the spill is indicated to occur on the opposite bank. Overtopping again occurs at section 5 (immediately downstream of the road bridge) on the right bank only (opposite to the proposed developments). The level at section 5 is 0.93m below the existing floor level of conversion no.1. Therefore from this modelling activity, there is shown to be *no risk* to the proposed development, up to and including the 0.1% AEP event.

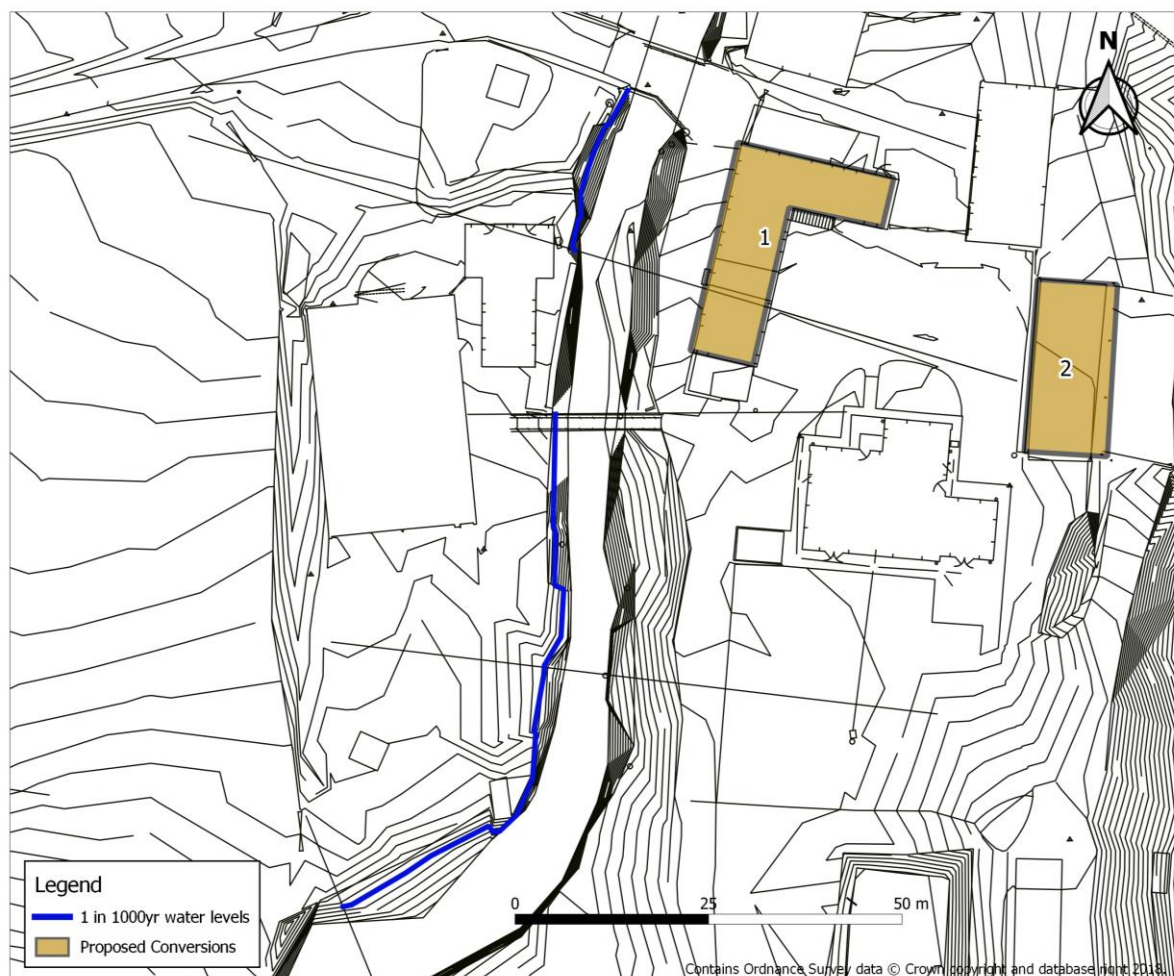


Figure 5 0.1% AEP out of bank modelled flood levels (as projected from the 1D model to site contour data)

3.3.3 Sensitivity testing

The robustness of the model was tested by undertaking sensitivity runs for the model assumptions. All sensitivity analyses were carried out for the baseline 1% AEP (+30% climate change) event.

- Flow/time hydrograph (+/-5%)

The 1D inflow hydrograph (upstream) was adjusted by +/-20%.

- Manning's n roughness coefficients (+/-20%)

The roughness of the channel sides and channel bed were represented using Manning's n , these values were amended by +/-20% to quantify the model sensitivity to the values selected.

- Downstream boundary (+/-20%)

The downstream boundary on the 1D model was adjusted by +/-20%.

Table 2 Changes to water level by cross section, for each sensitivity run

Cross section	100 year + CC flood stage (mAOD)	Mannings +20%	Mannings -20%	Flow +20%	Flow -20%	Downstream boundary +20%	Downstream boundary +20%
1	146.29	+0.12	-0.12	0.12	-0.12	-0.05	+0.07
2	147.22	+0.13	-0.15	0.13	-0.15	0.00	+0.03
3	147.84	+0.14	-0.16	0.14	-0.16	0.00	0.00
4	148.15	+0.14	-0.16	0.14	-0.16	0.00	0.00
5	148.64	+0.13	-0.15	0.13	-0.15	0.00	0.00
6	149.21	-0.12	+0.47	0.18	-0.20	0.00	0.00
7	149.45	+0.03	+0.39	0.19	-0.18	0.00	0.00

Rows bolded in Table 2, again show those cross sections adjacent (and therefore most pertinent) to the proposed conversions. The sensitivity runs show that the model is most sensitive to changes in Mannings values for the river bed and banks, with a largest relative increase in flood levels upstream of the road bridge, at section 6 for the -20% Mannings scenario. This increase in levels, causes a surcharge of the bridge (levels of 149.68mAOD, relative to the bridge soffit at 149.553mAOD). There is however no overtopping of the bridge deck levels and levels are contained to the north of the road bridge (i.e. no overland flow route identified towards the proposed conversions). This level upstream of the site also remains below the current floor level (149.77mAOD) for conversion no.1, with a freeboard of 9mm. It is noted that should there be an unforeseen flow route to the proposed conversion, flood levels would fall with the corresponding ground levels in this area and contours indicate flow would drain westwards, back to the River Clydach. This large relative increase in flood levels upstream of the road bridge, is caused by a large increase in velocities at this location relative to the baseline run (2.53m/s, compared to 1.89m/s), which has a greater impact upon water levels than the relative increase in conveyance (due to the v^2 component of energy head loss through the bridge).

As shown in Table 2, there are significant head losses across this structure as a result of the higher velocities (see comparison to baseline levels for cross sections 5 and 6).

3.3.4 Blockage runs

The footbridge at cross section 3 has no piers within the river and water levels are not predicted to reach the soffit (Section 3.3), so there is no increased risk of blockage. A blockage assessment is therefore not necessary for the footbridge.

The road bridge between cross sections 5 and 6 has piers within the river channel, and so a 20% blockage scenario was modelled by reducing the width of the bridge opening from 5.18m to 4.14m. This scenario is based upon the same assumptions as use in the previous FCA prepared for the Plas Farm site⁵. Relative to NRW guidance on modelling blockage scenarios⁶ it was concluded that this blockage factor (slightly less than medium risk of blockage) was appropriate, on grounds that the structure contains a wide (over 5m width) opening, which does not appear to be particularly susceptible to blockages. The model was then run for the 1% AEP+CC event. The results are summarised in Table 3.

Table 3 Summary of blockage assessment results (greyed numbers indicate no change from baseline levels)

Cross section	LB elevation (mAOD)	RB elevation (mAOD)	1% AEP + climate change flood stage (mAOD)
1	146.945	146.852	146.29
2	148.328	147.253	147.22
3	148.482	148.509	147.84
4	149.309	148.971	148.15
5	150.035	148.265	148.64
6	149.827	150.043	149.85 (+0.64)
7	151.286	150.375	150.01 (+0.56)

Table 3 demonstrates that the introduction of a blockage at the bridge increases the flood levels upstream of the road bridge (i.e. at cross sections 6 and 7). The water level at cross section 6 (immediately upstream of the road bridge) *does* exceed the bridge soffit (149.55 m AOD), but *does not* overtop the bridge deck (150.08 mAOD). The blockage causes water to be out of bank at section 6 (upstream of the road bridge) on the left bank, however this is shown from the model results to be contained to the areas to the north of the road bridge and access track (as shown in Figure 6) and therefore do not pose a risk to the proposed development.

⁵ WHS. 2012. WHS2051 Plas Farm FCA v1.03 Final

⁶ NRW. 2015. Flood Risk Management: Modelling blockage and breach scenarios.



Figure 6 1% AEP+CC out of bank water levels as shown for the blockage scenario (projected to site contour data)

3.4 Surface Water Flooding

The NRW surface water flood map has been reviewed to identify the risk of pluvial flooding at the site. Surface water is shown to pond in the courtyard between the two proposed developments, draining towards the River Clydach. The surface water flood maps indicate that only a portion of building 1 is at risk, being only marginally exposed to the 0.1% AEP event. It is thus considered that the developments are not exposed to significant flood risk from surface water flooding.

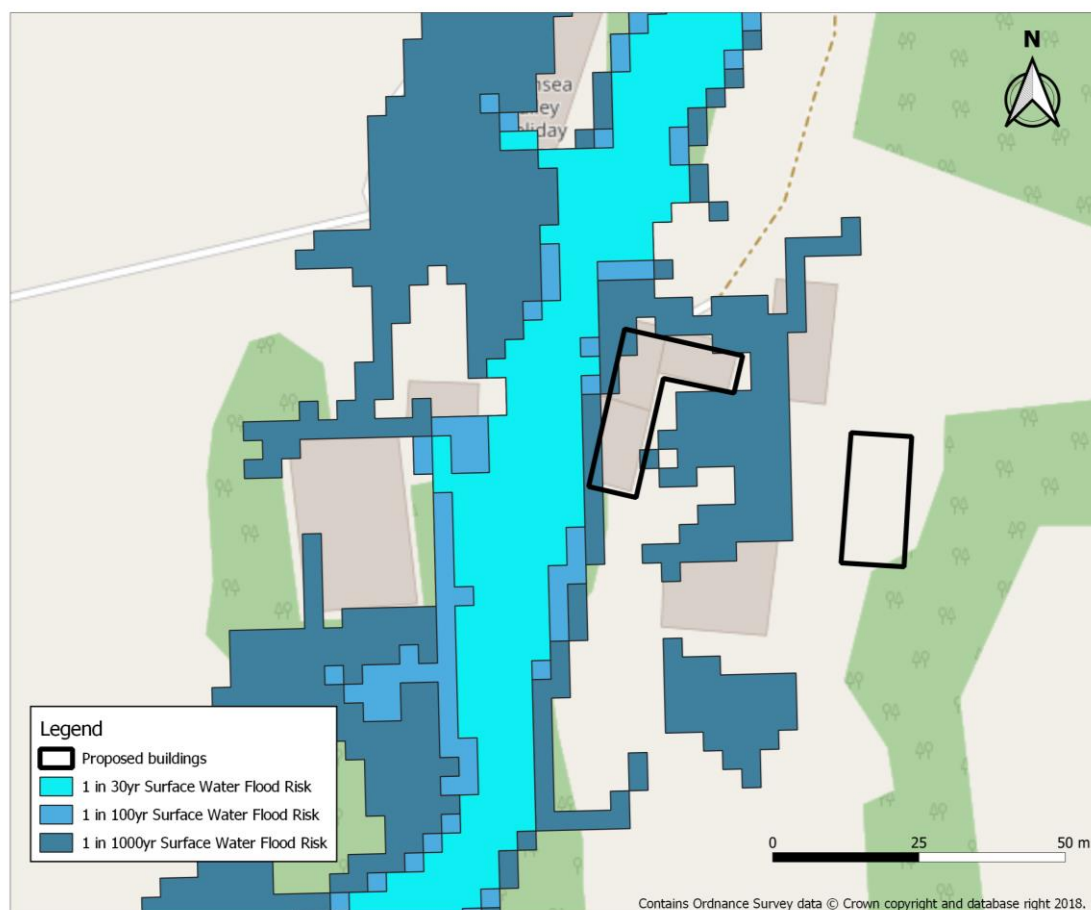


Figure 7 – Surface water flood risk

3.5 Historic Flooding

The historic flood map⁷ has been reviewed to understand historic flood risk at the development site. The online mapping indicates that there have been no historic flood events recorded by NRW at or near the development site.

⁷ Lle historic flood map accessed here: <http://lle.gov.wales/map#m=-3.37087,51.73614,17&b=europa&l=136;>

3.6 Groundwater Flooding

Groundwater flooding is defined as the emergence of groundwater at ground level, or the rising of groundwater into man-made locations that exceed the normal range of groundwater. Soilscape⁸ mapping indicates loamy and clayey soils, with impeded drainage. There is potential risk to the site from groundwater flood risk, however this can be managed provided a suitable drainage strategy is provided onsite.

4 Flood Consequence Assessment

4.1 Planning Policy

TAN 15 outlines the requirements for planning policy in Wales in relation to development and flooding, this FCA will identify the improvements that can be made to the site to ensure that flood risk to the existing buildings can be reduced and increase compliance with TAN 15.

It is noted that although the site is shown to lie within Flood Zone C2 according to the NRW Development Advice Map, this modelling exercise shows the proposed developments are *not* at risk from the River Clydach, up to and including the 0.1% AEP event.

TAN 15 requires that the development site will remain safe for its lifetime and not increase flood risk elsewhere, alongside ensuring users of the development face minimal risk to life.

4.2 Justification for Development

It is noted that this Flood Consequence Assessment refers to a change of use of existing farm outbuildings to use as a holiday cottage, garages and tourist facilities. Building number 1 (closest to the left bank) is proposed to have accommodation on the first floor and tourist facilities on the ground floor, whilst the second building is proposed to not hold accommodation, with only garages on the ground floor and tourist facilities on the first floor. For the purposes of interpretation of these proposals according to TAN15 guidance, the first building may be categorised as a residential dwelling, with the second as commercial.

Previous developments of a similar nature (change of use of farm outbuildings to holiday cottages) have taken place at the Plas Farm estate. These applications (submitted in 2012), were also formally supported by an FCA, serving to quantifying flood risk to the site through use of a 1D hydraulic model, the same as used in this assessment.

⁸ Cranfield Soil and Agrifood Institute. Accessed at: <http://www.landis.org.uk/soilscape/>

4.3 3rd Party Impacts

The site is shown not to be at risk from fluvial flooding, and at minimal risk from pluvial flooding. Furthermore, as this is a change of usage of an existing building (with no increase in site footprint) there will not be a significant increase in third party impacts with respect to flood risk.

4.4 Access and Egress

The main access route from the Plas Farm estate east of the River Clydach includes a road bridge over the watercourse. The hydraulic modelling outlined in this report shows the bridge deck not to be overtopped for all events, including blockage runs performed for the structure. The proposed access route shown in Figure 8 is shown by the modelling exercise in this report to not be inundated for any flood event modelled.

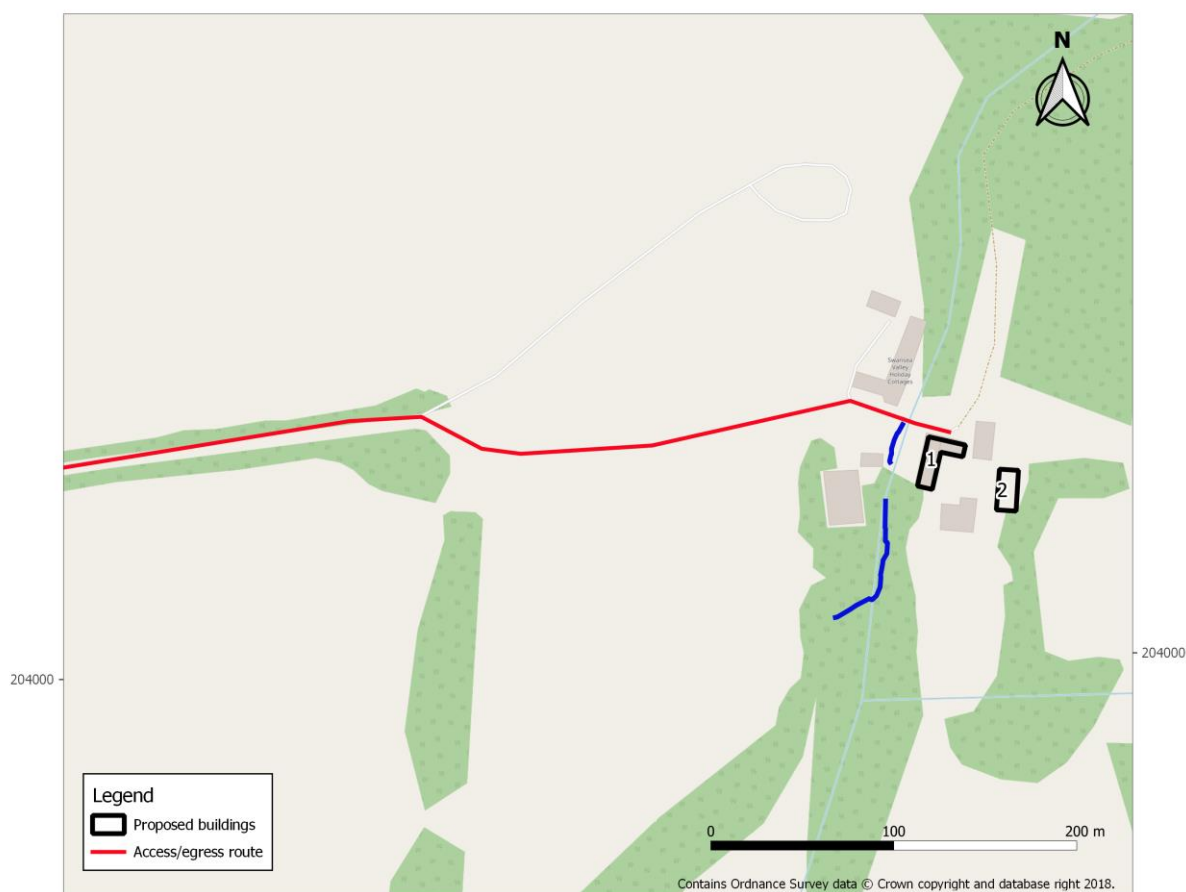


Figure 8 Proposed Access/Egress route

5 Conclusion

The key findings of the FCA are listed below:

- This FCA addresses the proposed change of use of two farm outbuildings to holiday accommodation and tourist facilities. As such this FCA details expected flood levels, upon which design specifications such as finished floor levels can be better informed.
- The developed land currently lies within Flood Zone 3 according to the NRW flood map and within Flood Zone C2 of the DAM.
- The predominant flood risk to the site is fluvial, from the River Clydach.
- There is no historic evidence of flooding at the site.
- Hydraulic modelling has indicated that the existing development is not at risk of flooding, up to and including the 0.1% AEP event.
- As there is a pre-existing development, there are no increases in flooding downstream or increased risk to third parties.
- Mitigation measures in the form of evacuation response, preparedness and access/egress routes have been proposed to ensure safety of the residents in the event of a flood.

From this analysis, it is considered that flood risk to the site will be manageable for the 1% AEP +CC event and the development will remain safe for its lifetime.

Appendix 1 NRW email correspondence

From: ["Wicks, Richard" <Richard.Wicks@cyfoethnaturiolcymru.gov.uk>](mailto:Richard.Wicks@cyfoethnaturiolcymru.gov.uk)
 To: ["Joel Leyshon Jones" <joel.leyshon-jones@hydrosolutions.co.uk>](mailto:joel.leyshon-jones@hydrosolutions.co.uk)
 Date: 2/21/2019 2:20:18 AM
 Subject: RE: FCA at Plas Farm, Pontdardawe

Dear Joel,

Your proposal does not seem unreasonable to ascertain a flood level relative to a floor level, but please be aware that we are currently undertaking a national flood mapping exercise using 2D modelling; preliminary draft results for this location show that there is out of bank flow on the right bank. When we publish this information it may cause insurance problems for your client as the properties on the right bank will be within the flood outline. The only way that this could be challenged is through a formal Flood Map challenge and to do that we would expect a 1D/2D model with cross sections extending further upstream and downstream than your proposals.

Regards

Richard Wicks BSc (Hons) CEng MICE

Arweinydd Tîm Dadansoddi Perygl Llifogydd / Team Leader Flood Risk Analysis

Cyfoeth Naturiol Cymru / Natural Resources Wales

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Correspondence in Welsh is welcomed, and we will respond in Welsh without it leading to a delay

From: Joel Leyshon Jones <joel.leyshon-jones@hydrosolutions.co.uk>

Sent: 20 February 2019 15:15

To: Wicks, Richard <Richard.Wicks@cyfoethnaturiolcymru.gov.uk>

Subject: FCA at Plas Farm, Pontdardawe

Dear Richard,

We are in the process of developing an FCA for a proposed change of use for two outbuildings to holiday cottages, at Plas Farm, Pontdardawe NGR 274854, 204065 (please see the attached site plan- proposed conversion of both 'Farm Building' structures on west bank of River Clydach).

Current NRW flood maps show the site to be within FZ3, however mapping in this region appear to be relatively coarse, whilst also misaligning with the watercourse, suggesting that JFLOW data is possibly informing the flood maps and there may have been changes to the channel course.

- A previous FCA developed in 2012 saw the planning approval for three buildings on the same site, also within the FZ3, and also for change of use from farm outbuildings to holiday cottages.
- This approval was granted on the basis of a 1D (ISIS) hydraulic model, the outputs of which showed water levels to be largely contained within bank for all events up to 0.1%AEP. Where spill occurred, this remained below ground levels for the proposed developments (levels extrapolated from 1D to contour levels).
- This 1D model incorporated eight river cross sections (including one bridge structure), with steady state runs made, to include the 1%, 1%CC and 0.1% events.

Could you advise if from the perspective of NRW, on the understanding that hydrology inputs are updated to include new climate change allowances, use of this 1D model would in principal remain suitable for the purposes of informing an FCA of this nature?

If you require any further info, do let me know,

Kind regards,

Joel Leyshon-Jones
Consultant

1/2/2022

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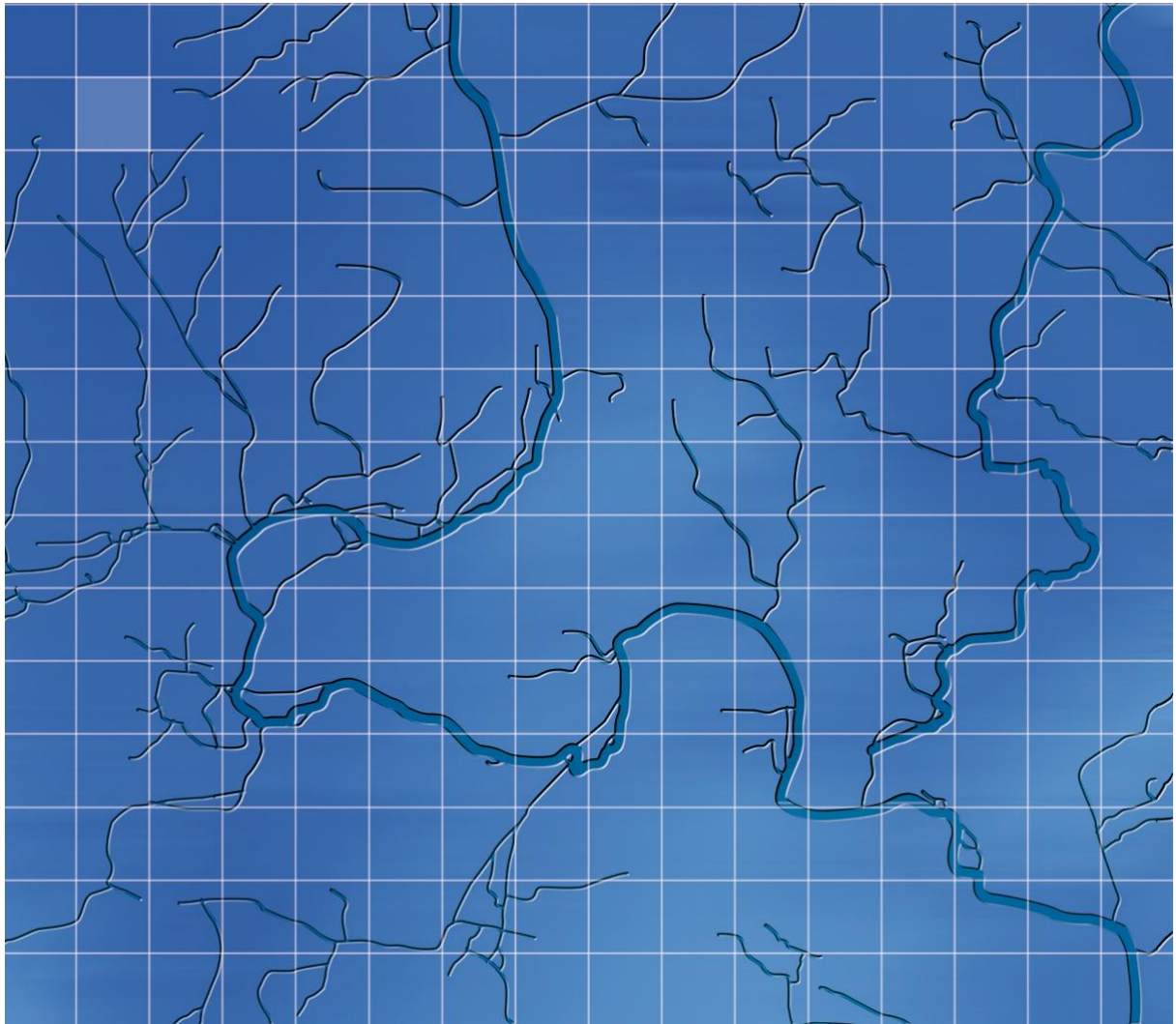
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Appendix 2 Plas Farm Hydrology Peak Flow Report

Swansea Valley Holiday Cottages

February 2019

Peak Flow Estimate for River Clydach



Wallingford HydroSolutions Limited

Swansea Valley Holiday Cottages

Flood Peak Flow Estimate for River Clydach

Document issue details

Version number	Issue date	Issue status	Issuing Office
1	25/02/19	Draft	Cardiff

For and on behalf of Wallingford HydroSolutions Ltd.

Prepared by Joel Leyshon-Jones

Approved by Daniel Hamilton

Position Consultant

Date **25/02/2019**

This report has been prepared by WHS with all reasonable skill, care and diligence within the terms of the Contract with the client and taking account of both the resources allocated to it by agreement with the client and the data that was available to us. We disclaim any responsibility to the client and others in respect of any matters outside the scope of the above. This report is confidential to the client and we accept no responsibility of any nature to third parties to whom this report, or any part thereof, is made known. Any such party relies on the report at their own risk.



The WHS Quality Management system is certified as meeting the requirements of ISO 9001:2015 and ISO 14001:2015 providing Environmental Consultancy (including monitoring and surveying), the development of Hydrological Software and associated Training.



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1 Requirements

The customer requires the development of design flood estimates for the development of two holiday cottages at a site near Pontardawe. NGR 274854 204082.

2 The Catchment

The catchment boundary is presented in Figure 1. The FEH Web Service¹ was used to derive the catchment descriptors. The area of the FEH Web Service boundary is 3.15km². Table 1 presents the relevant catchment descriptors. The catchment has an URBEXT2000 value of 0.000 hence is classed as 'essentially rural' according to FEH guidance. The catchment is relatively impermeable, assigned a BFIHOST characteristic of 0.365. The majority of the catchment is underlain by sandstone, with only superficial deposits (till) in evidence, close to the river channel. The catchment is not affected by the presence of lakes and is therefore assigned a FARL value of 1.

Table 1. Relevant catchment descriptors from the FEH Web Service²

Catchment Descriptor	
Area (km ²)	3.15
SAAR (standard average annual rainfall 1961 - 1990mm)	1736
BFIHOST (baseflow index derived from HOST soils data)	0.365
FARL (index of flood attenuation due to reservoirs and lakes)	1
FPEXT (extent of flood plain)	0.0125
PROPWET	0.62
URBEXT 2000	0.000

¹ <https://fehweb.ceh.ac.uk/GB/map>

² Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

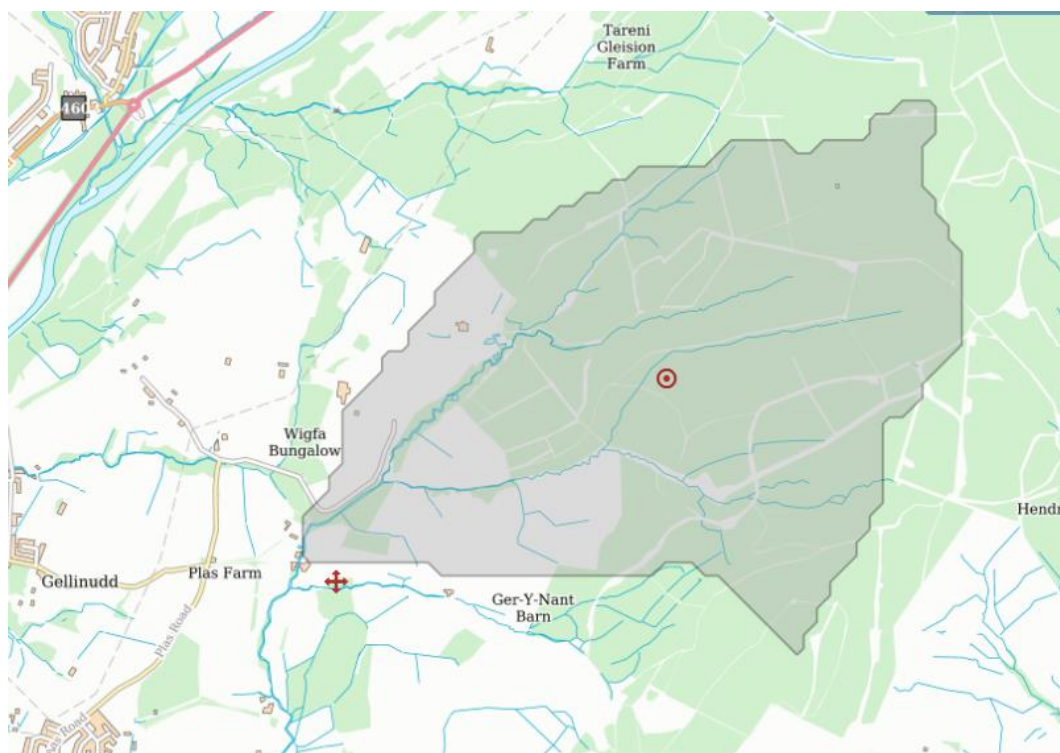


Figure 1 The FEH Web Service derived catchment is shown by the grey boundary. Contains OS data © Crown Copyright (2019) Contains CEH data © and database right NERC (CEH) 2019

3 Outline of Methodology

The flood estimates have been developed using the Flood Estimation Handbook statistical and rainfall runoff methods. The statistical methods are those as published by the Institute of Hydrology in 1999³ with updates included in the latest version of WINFAP-FEH 4⁴ as described by Kjeldsen *et al.*,⁵ and the WHS technical guidance⁶. These methods require the estimation of a normalised flood frequency curve, termed the flood growth curve and the estimation of the normalising variable; the median annual flood, QMED. The current version of NRFA Peak Flows dataset available for use in this study was NRFA Peak Flows v7⁷.

The rainfall-runoff methods are those first published by Kjeldsen⁸, which were subsequently updated in 2015 and implemented within the ReFH2.2 software⁹ as described in the WHS technical guidance¹⁰.

³ Robson, A. and Reed, D., 1999. *Flood Estimation Handbook Volume 3: Statistical Procedures for Flood Frequency Estimation*. Institute of Hydrology, Wallingford, pp338.

⁴ <https://www.hydrosolutions.co.uk/software/winfap-4/>

⁵ Kjeldsen, T.R., Jones, D.A., and Bayliss, A.C., 2008. *Improving the FEH statistical procedures for flood frequency estimation*. Environment Agency, Bristol, pp137.

⁶ <https://www.hydrosolutions.co.uk/software/winfap-4/literature/>

⁷ <https://nrfa.ceh.ac.uk/peak-flow-data>

⁸ Kjeldsen, T. R. 2007. The revitalised FSR/FEJ rainfall-runoff method. Supplementary Report No.1. CEH.

⁹ <https://www.hydrosolutions.co.uk/software/refh-2/>

¹⁰ https://www.hydrosolutions.co.uk/software/refh-2/supporting_literature/

4 Peak Flow Estimation using the statistical method

As the site is ungauged, the approach adopted for estimating QMED has been to develop an FEH catchment descriptor-based estimate and to review the availability of potentially suitable donor catchments to form the basis of a data transfer exercise that would improve the QMED estimate. This is the standard application of the FEH methodology. The pooled methodology for estimation of the growth curve is then applied.

4.1 Derivation of the Median Annual Flood

The QMED for the location was first estimated from catchment descriptors ($Q_{med_{cds}}$) as $4.97\text{m}^3\text{s}^{-1}$.

Estimates of QMED from observed data ($Q_{MED_{obs}}$) at donor stations can be used to adjust the estimate of $Q_{MED_{cds}}$ at the subject site. Possible donor catchments are initially sought on the basis of being geographically close. Along with geographical distance the similarity of catchment descriptors; Area, SAAR, FARL and BFIHOST with the target catchment are also considered.

The general pattern of $Q_{MED_{obs}}$ to $Q_{MED_{cds}}$, is to underestimate flows from the catchment descriptors. It was noted that most of the catchments were significantly larger than the target catchment (in excess of ten times the area), however they remained suitably similar in other key characteristics to merit inclusion in the calculation of the QMED estimate. An exception to this being the Rhondda Fawr @ Tynewydd (57017), which, though being most similar in area to the target catchment, shows a substantially different ratio of observed QMED to descriptor QMED, relative to the other catchments. This catchment also has a substantially higher SAAR value than the target catchment (and other prospective donor stations). The Melte @ Pontneddfecha was added to the group on the basis of its similarity to the target catchment.

As a result, six stations were chosen in the donor group, from which to inform the QMED estimate. Table 2 presents the geographically closest six stations (five of which were selected) along with the Melte @ Pontneddfechan.

The $Q_{MED_{cds}}$ value, was unchanged from the rural estimate due to the lack of development in the catchment (urban adjustment factor of 1.000). The donor adjusted, rural QMED value is $6.071\text{ m}^3\text{s}^{-1}$. The catchment has an URBEXT value of 0.000 therefore the associated urban adjustment factor (UAF) is 1.00. This means there is no change in the QMED value when urbanisation is accounted for, the best estimate of the median annual flood for the catchment therefore remain 6.071. This value should be used to scale the flood growth curves.

Flood Peak Flow Estimate for River Clydach

Table 2. List of donor catchments considered for QMED adjustment¹¹

Station	Distance (km)	URBEXT2000	QMED Observed (m^3s^{-1})	QMED CDs (urabn) (m^3s^{-1})	Area (km^2)	SAAR (mm)	BFIHOST	FARL	Years of data	Accept or Reject	Comments
Target Catchment	0	0	0	0	3.15	1736	0.365	1	0		
58008 (Dulais @ Cilfrew)	4.54	0.018	56.5	46.91	43.45	1806	0.377	0.999	45	Accept	
59001 (Tawe @ Ynystanglws)	7.4	0.024	253.057	184.98	227.45	1890	0.407	0.996	43	Accept	
58012 (Afan @ Marcroft Weir)	11.35	0.02	94.927	80.99	89.71	2036	0.452	1	37	Accept	
58002 (Neath @ Resolven)	14.98	0.011	220	180.36	190.70	1946	0.346	0.983	39	Accept	
57017 (Rhondda Fawr @ Tynewydd)	16.4	0.016	23.46	31.03	16.64	2458	0.317	0.999	16	Reject	Substantially higher SAAR
60009 (Sawdde @ Felin-y-cwm)	17.84	0.001	126.862	63.71	78.86	1794	0.448	0.995	38	Accept	
58006 (Mellte @ Pontneddfechan)	21.04	0	86.911	75.30	65.32	1981	0.322	0.975	46	Accept	

¹¹ Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

4.2 Derivation of the Growth Curve

Within the FEH methodology flood growth curves for ungauged sites are formed by pooling annual maxima data from similar catchments which are flagged as being suitable for pooling. A threshold of 500 station-years is required (a sum of record lengths) and thus an initial pooling group was formed for the development of the flood growth curve by pooling data from 18 catchments. Two stations, the Camel at Camelford and Rhondda Fawr @ Tynewydd were removed as they had a negative L-Skew value value which reflects the fact that the distributions are bounded. This may be valid, being a result of sampling error, however it may also indicate issues with the quality of the data. Both records were removed as a precautionary approach which may result in a conservative (high) estimate of the growth factors within the target catchment.

A final pooling group containing 16 stations and 523 station years was derived. Table 3 shows the full list of pooling group members along with the reason for any stations being removed or retained. The distance shown is the distance from each candidate station to the sites in a similarity distance space (the FEH distance measure).

Flood Peak Flow Estimate for River Clydach

Table 3. Pooling group selection and reasons for retaining or removing from final pooling group.¹²

Station	Distance SDM	AREA (km ²)	SAAR (mm)	FARL	URBEXT 2000	Accept or Reject	Comments
91802 (Allt Leachdach @ Intake)	1.265	6.54	2554	0.992	0	Accept	
45816 (Haddeo @ Upton)	1.279	6.81	1210	1	0.005	Accept	
28033 (Dove @ Hollinsclough)	1.378	7.92	1346	1	0	Accept	
76011 (Coal Burn @ Coalburn)	1.445	1.63	1096	1	0	Accept	
92002 (Allt Coire Nan Con @ Polloch)	1.504	8.06	2541	0.989	0	Accept	
54022 (Severn @ Plynlimon Flume)	1.583	8.75	2481	1	0	Accept	
71003 (Croasdale Beck @ Croasdale Flume)	1.718	10.71	1882	1	0	Accept	
25003 (Trout Beck @ Moor House)	1.834	11.4	1905	1	0	Accept	
27051 (Crimple @ Burn Bridge)	1.899	8.17	855	1	0.006	Accept	
49006 (Camel @ Camelford)	1.967	12.52	1418	1	0.003	Reject	Negative L-Skew
25011 (Langdon Beck @ Langdon)	1.985	12.79	1463	1	0.001	Accept	
47022 (Tory Brook @ Newnham Park)	2.103	13.43	1403	0.942	0.014	Accept	
206006 (Annalong @ Recorder)	2.135	14.44	1704	0.981	0	Accept	
69047 (Roch @ Littleborough)	2.337	14.78	1353	0.89	0.034	Accept	

¹² Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

Flood Peak Flow Estimate for River Clydach

Station	Distance SDM	AREA (km ²)	SAAR (mm)	FARL	URBEXT 2000	Accept or Reject	Comments
57017 (Rhondda Fawr @ Tynewydd)	2.419	16.64	2458	0.999	0.016	Reject	Negative L-Skew
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.48	16.08	1044	0.991	0.006	Reject	
25019 (Leven @ Easby)	2.605	15.09	830	1	0.004	Accept	-
27010 (Hodge Beck @ Bransdale Weir)	2.721	18.82	987	1	0.001	Accept	-

4.3 Results

A three-parameter generalised logistic (GL) distribution was used, which is the FEH recommended distribution for use within UK flood data to model the growth curve. Figure 2 shows the estimated flood frequency curve for the subject site and Table 4 presents the flood growth curve indexed by return period. The growth curve was also adjusted for urbanisation.

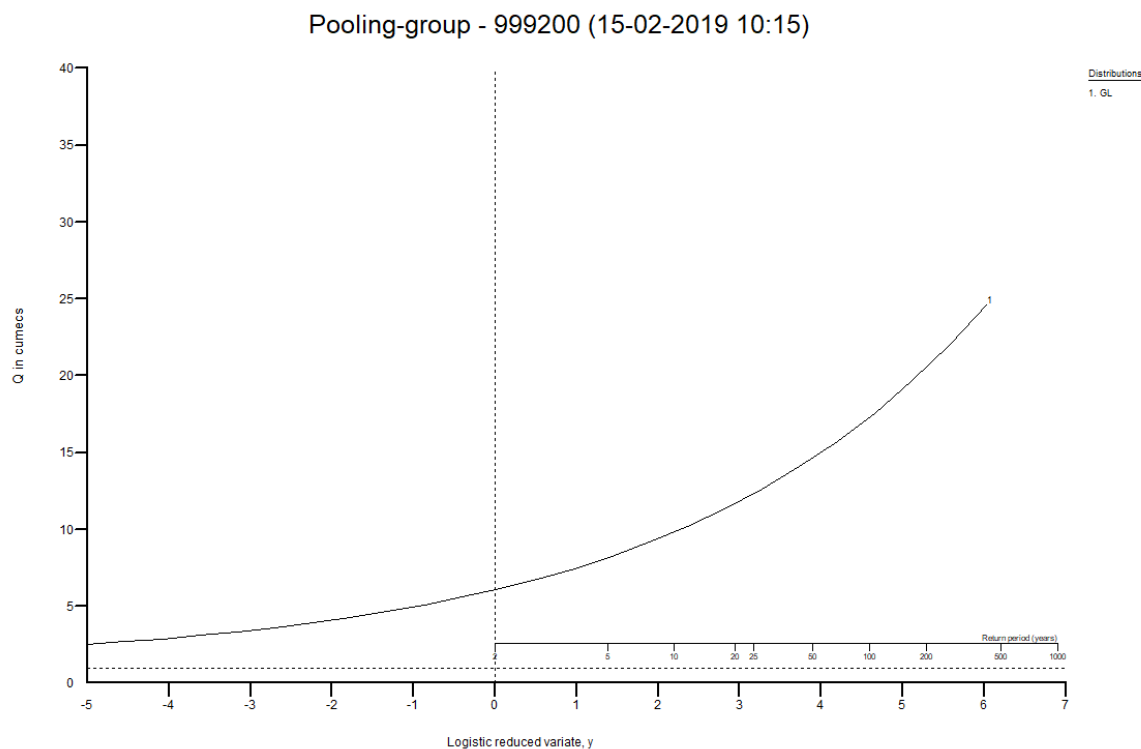


Figure 2 Flood frequency curve

Table 4. Growth curve¹³

Return Period (years)	Growth Curve for Location
2	1
25	2.03
50	2.41
100	2.85
500	4.25
1000	5.06

¹³ Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

The final peak flow is presented in Table 5. These represent the QMED value (2 year return period) scaled by the growth curve.

Table 5 Flood Peak flow estimate

Return Period (years)	Peak Flow estimate (m ³ /s)
2	6.07
25	12.34
50	14.62
100	17.32
500	25.80
1000	30.69

5 Peak Flows Estimation using the Rainfall- Runoff methodology

The catchment was modelled using the ReFH 2.2 software. This uses standard design rainfall events and catchment descriptors to produce hydrographs for the site. The recommended duration and timestep of 2.75 hours and 0.25 hours respectively were used to define the rainfall event. Default parameters for urbanisation were used, however as the catchment is essentially rural the final peak flows are not sensitive to these.

Table 6 Peak Flow Estimates as Returned by ReFH 2 Software¹⁴

Return Period (years)	Peak Flow estimate (m ³ /s)
2	4.26
25	8.14
50	9.27
100	10.51
500	14.72
1000	17.89

¹⁴ Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

6 Final Hydrology

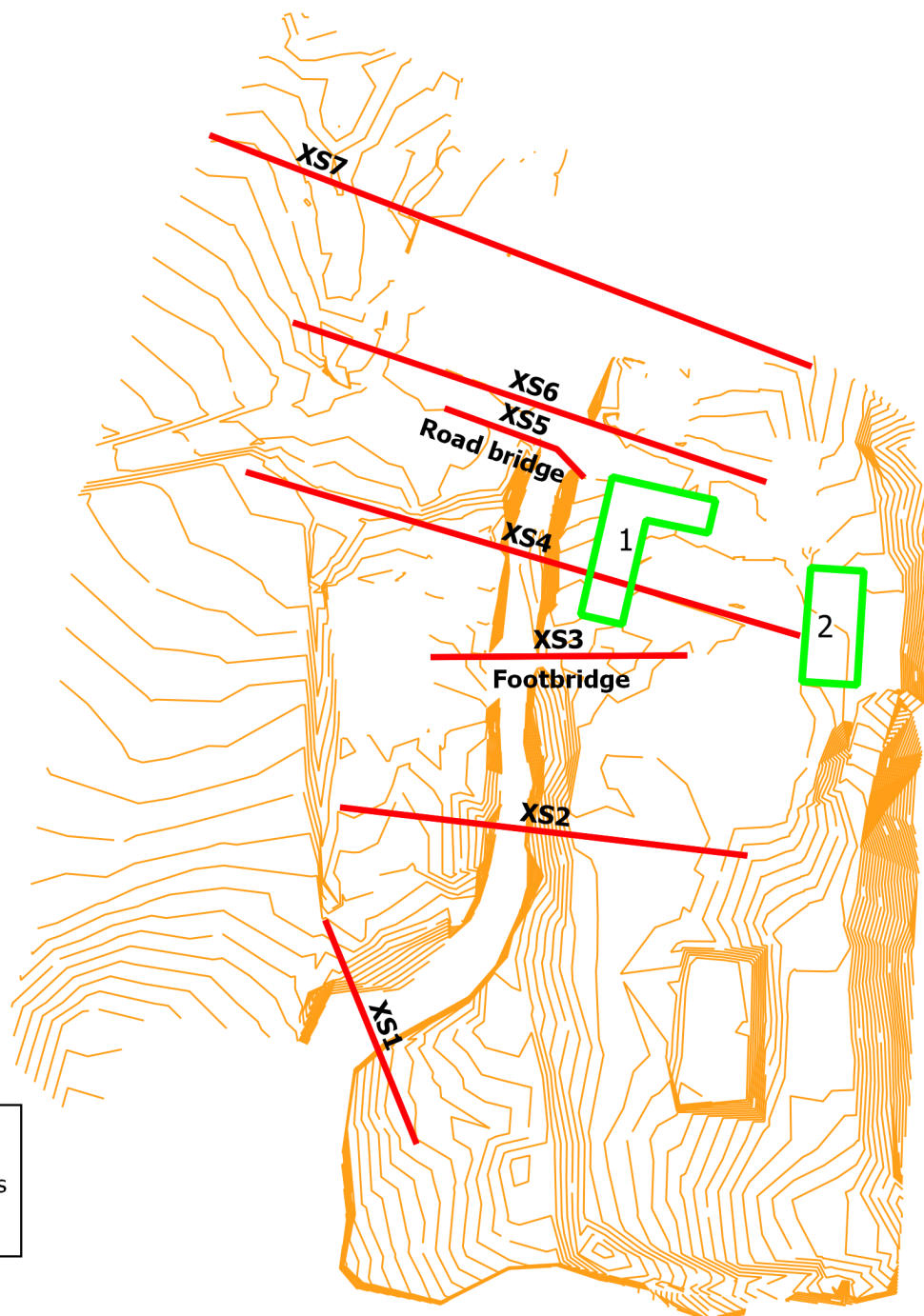
The flood peaks estimated using the rainfall runoff methodology are higher than those produced using the statistical method. Based on NRW guidance the statistical estimates are used for return period up to and including 1:100. The flow estimates for the return periods above 1:100 are estimated by rescaling the statistical 1:100year peak flow estimate by the ratio between the ReFH 2.2 peak flow estimate for the target return period and the 1:100-year return period. The final flood peaks are presented in Table 7.

Table 7 Final Peak Flows Estimates¹⁵.

Return Period (years)	Peak Flow estimate (m ³ /s)
2	6.07
25	12.34
50	14.62
100	17.32
500	24.26
1000	29.48

¹⁵ Results based upon FEH methodology and data, CEH (2015) 'CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK'

Appendix 3 Survey plan of Plas Farm



Legend

-  Proposed Conversions
-  Cross Sections

0 10 20 30 40 m



204000

Appendix 4 Cross section data

Cross Section	Easting (m)	Northing (m)	Elevation (m AOD)
1	274838.91	203995.17	147.375
1	274834.83	204005.90	146.945
1	274834.62	204006.46	145.105
1	274833.58	204009.19	145.185
1	274832.63	204011.69	145.380
1	274832.04	204013.24	145.583
1	274831.12	204015.64	146.852
1	274828.78	204021.80	147.563
2	274879.58	204028.71	150.262
2	274862.65	204031.15	149.705
2	274858.90	204031.68	149.678
2	274855.36	204032.19	148.328
2	274853.36	204032.48	147.185
2	274853.13	204032.51	145.763
2	274852.25	204032.64	145.705
2	274851.62	204032.73	145.763
2	274851.33	204032.77	145.818
2	274850.32	204032.92	146.009
2	274848.74	204033.14	147.253
2	274847.13	204033.38	147.678
2	274831.16	204035.67	148.211
3	274872.90	204053.04	149.828
3	274871.03	204053.07	149.817
3	274857.89	204053.31	149.518
3	274855.91	204053.35	148.593
3	274855.13	204053.36	148.482
3	274854.56	204053.38	146.780
3	274853.39	204053.40	146.559
3	274852.96	204053.40	146.396
3	274852.06	204053.42	146.338
3	274850.67	204053.45	146.540
3	274849.64	204053.47	147.215

Cross Section	Easting (m)	Northing (m)	Elevation (m AOD)
3	274849.31	204053.47	148.509
3	274842.57	204053.60	148.713
4	274886.61	204055.19	149.940
4	274867.02	204061.50	149.852
4	274862.04	204063.10	149.224
4	274857.88	204064.44	149.309
4	274856.36	204064.93	147.331
4	274854.06	204065.67	146.863
4	274853.53	204065.85	146.779
4	274852.39	204066.21	146.712
4	274851.98	204066.34	146.665
4	274851.89	204066.38	146.826
4	274851.02	204066.65	148.971
4	274849.79	204067.05	149.171
4	274844.42	204068.78	149.325
4	274841.89	204069.60	149.359
4	274838.91	204070.56	149.579
4	274829.02	204073.75	149.748
4	274820.75	204076.41	149.490
5	274861.08	204075.09	149.993
5	274860.40	204075.84	150.035
5	274860.10	204076.16	148.558
5	274859.72	204076.58	147.698
5	274859.42	204076.91	147.580
5	274858.58	204077.84	147.495
5	274858.12	204078.34	147.469
5	274857.42	204078.61	147.319
5	274856.60	204078.94	147.353
5	274856.47	204078.99	148.103
5	274856.25	204079.07	148.265
5	274855.54	204079.35	150.223
5	274845.00	204083.49	150.170

Cross Section	Easting (m)	Northing (m)	Elevation (m AOD)
6	274882.99	204073.87	150.256
6	274867.34	204079.58	150.406
6	274862.40	204081.38	149.827
6	274862.10	204081.49	149.470
6	274862.02	204081.51	148.512
6	274861.53	204081.69	147.802
6	274861.27	204081.79	147.667
6	274860.46	204082.08	147.553
6	274859.08	204082.59	147.529
6	274858.09	204082.95	147.628
6	274857.89	204083.02	148.191
6	274857.46	204083.18	149.358
6	274857.01	204083.34	150.043
6	274855.36	204083.94	149.987
6	274837.97	204090.28	150.234
6	274837.76	204090.36	150.292
6	274837.27	204090.54	150.737
6	274829.76	204093.27	150.950
6	274826.89	204094.32	150.684
7	274892.76	204086.08	151.425
7	274888.85	204087.69	151.088
7	274884.03	204089.68	151.028
7	274879.79	204091.43	151.108
7	274876.20	204092.91	151.286
7	274870.08	204095.43	148.224
7	274869.67	204095.61	148.092
7	274869.25	204095.78	147.959
7	274868.40	204096.13	147.920
7	274867.67	204096.43	147.978
7	274866.80	204096.79	148.092
7	274863.94	204097.97	150.375
7	274860.98	204099.19	150.376
7	274855.84	204101.31	150.308
7	274853.37	204102.33	150.225

Cross Section	Easting (m)	Northing (m)	Elevation (m AOD)
7	274842.33	204106.89	150.401
7	274842.23	204106.93	150.757
7	274829.05	204112.36	151.243