Cardiff Parkway Development Limited

Hendre Lakes

Drainage Strategy

HDL-ARP-DN-BG-REP-ECV-000008

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Contents

1 Project Overview

This report has been prepared to support the outline planning application (OPA) which is being submitted by Cardiff Parkway Ltd (CPDL) for the Hendre Lakes development. The development incorporates the following proposals:

"Outline planning permission, with all matters reserved, is being sought for: the construction of a business park (up to 90,000m² - Use Classes B1, B2 and B8), ancillary uses (Use Classes A1 and A3) and infrastructure associated with; biodiversity; landscape; drainage; walking, cycling and other transport modes. Together with the construction of a new transport hub facility, comprising railway station buildings (up to 1,500m²) including ancillary uses (Use Classes A1 and A3), 4 no. platforms, surface car park (up to 650 no. spaces), and associated infrastructure works at land to the south of St Mellons Business Park."

The OPA and Environmental Statement (ES) which will accompany the application will outline the proposals for the new development with the details to come forward at Reserved Matters Application stage. Following Pre-SAB application approval prior to the planning submission, Full SABS applications will be made and ratified during/post determination of the planning application prior to commencement of works. For the purpose of the OPA and associated assessments within the ES, it is assumed that the storm drainage systems would be constructed, operated and maintained in accordance to the principles as set out in this drainage strategy and submitted as part of the Pre-SAB application.

The purpose of this report is to outline the principles of the proposed drainage strategy for the proposed commercial development as well as outlining the existing constraints and challenges that exist within the site. It will also summarise the proposed diversion, protection and reinforcement works that may be required to existing drainage features to accommodate the Hendre Lakes development.

The report has been prepared based on what is known at the time of writing and will need to be reviewed and revised in subsequent design stages once further details of the proposed development is known and further engagement with the SuDS Approving Body and Dwr Cymru Welsh Water is completed. The Pre-SABS Application with the SABS is currently on-going.

2 The Site

2.1 Site Location and Description

The site for the Hendre Lakes development is located approximately 7km east of Cardiff, south east of St Mellons a suburb of Cardiff. St Mellons Business Park exists to the north of the site whilst Cypress Drive and Heol Las defines the western and eastern perimeter of the site respectively. Fortran Road and Cobol Road form the northern boundary of the site whilst agricultural fields exist to the south of the site. The South Wales Mainline Rail corridor, comprising two main lines and two relief lines supported on low height embankments, divides the site into the northern and southern areas. The development is proposed on a greenfield site currently used predominantly for agricultural purposes. The area to the north of the railway is allocated for the proposed commercial development whilst the south is proposed for mitigation purposes and to provide maintenance access south of the railway line.

An existing reen network also exists within the site. The reen network is formed of primary and secondary reens and their primary functions are:

1. control water levels in summer and winter within the network, for water supply/irrigation in summer and increase capacity of reen network in winter;
2. maintain ecological value of the land (flora and fauna); and
3. maintain integrity of reen banks especially in dry period.

The reen network within the site forms part of a wider reen network within the Caldicot and Wentloog Levels. The primary reens are controlled and managed by Natural Resources Wales (NRW) and their primary control mechanism to maintain consistent summer and winter penning levels are a series of sluices located along the reens. The primary reens located within the site consists of:

- Faendre Reen – forms the western boundary of the development;
- Green Lane Reen – forms the eastern boundary of the development;
- Green Lane Branch – forms the northern boundary of the development and transfers flows between Green Lane and Faendre Reens;
- Ty Ffynnon Reen – transfers flow between Faendre and Green Lane Reens and dissects the northern area of the site in two from east to west.
- Railway Reen – transfers flow from Ty Ffynnon Reen south below the existing railway line via a culvert and connects to the reen network south of the railway.

The site is centred at approximate National Grid Reference 325029, 181152. Figure 1 below depicts the site location. Refer to Appendices A1 & A2 for additional drawings and information.

Figure 1: Site Location (Imagery ©2019 Bluesky, Infoterra Ltd & COWI A/S, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group, Map data ©2019)

2.2 Site Topography and Levels

A topographic survey for the site was undertaken in January 2018. The survey covered the majority of the site excluding the railway corridor. The existing ground profile within the site is generally flat where the levels approximately vary between 4.8m and 5.2m above ordnance datum (AOD) with small localised areas varying between 4.6m and 5.6m AOD. The surrounding rail and road corridors are generally higher than within the site. The varying road levels are summarised in Table 1 below.

Table 1: Summary of Road Levels

Road	Levels (m AOD)
Cypress Drive	7.2 – 8.6
Fortran Road	8.3 – 10.6
Cobol Road	5 – 7.3

Heol Las	4.7 – 5.3
Cypress Drive / Fortran Road Signalised Junction	8.6 – 10.7
Heol Las Rail Overbridge	5.3 – 13.3

Although no topographical survey information is currently available for the rail corridor it is understood that the railway is positioned on an embankment, typically 1 to 2m above the sites ground level. Light Detection and Ranging (LIDAR) survey suggests that the embankment levels along the railway vary between 7.0m to 6.1m AOD within the site boundary from west to east respectively.

The water levels within the existing reen network are controlled by NRW. Table 2 below summarises the summer and winter penning levels across the site. This is based on information provided by NRW, refer to Appendices A2 & A4 for further details.

Table 2: Summary of Reen Water level

Reen	Actual Summer Penning Levels (m AOD)	Actual Winter Penning Levels (m AOD)
Faendre	4.59	4.00
Green Lane (North of Railway)	4.40	4.05
Green Lane (South of Railway)	3.95	3.35
Ty Ffynnon	4.40	4.05
Railway	4.15	3.80

Refer to drawings included in Appendices A3 & A4 for additional information.

2.3 Flooding

Welsh Government (WG) Technical Advice Note 15 (TAN15) Development Advice Maps (DAM) and the Natural Resources Wales (NRW) flood risk maps have been reviewed to determine if the development is at risk of fluvial, pluvial and tidal flood risk. Figures 2, 3 and 4 below demonstrates that the site is at risk of flooding from both a tidal flood event from overtopping sea defences and pluvial flood event resulting from extreme rainfall events transmitted via the reen network. As a result, a Flood Consequence Assessment (FCA) is needed and further details can be found in the FCA which is accompanied by the outline planning application and included in Appendix A5.

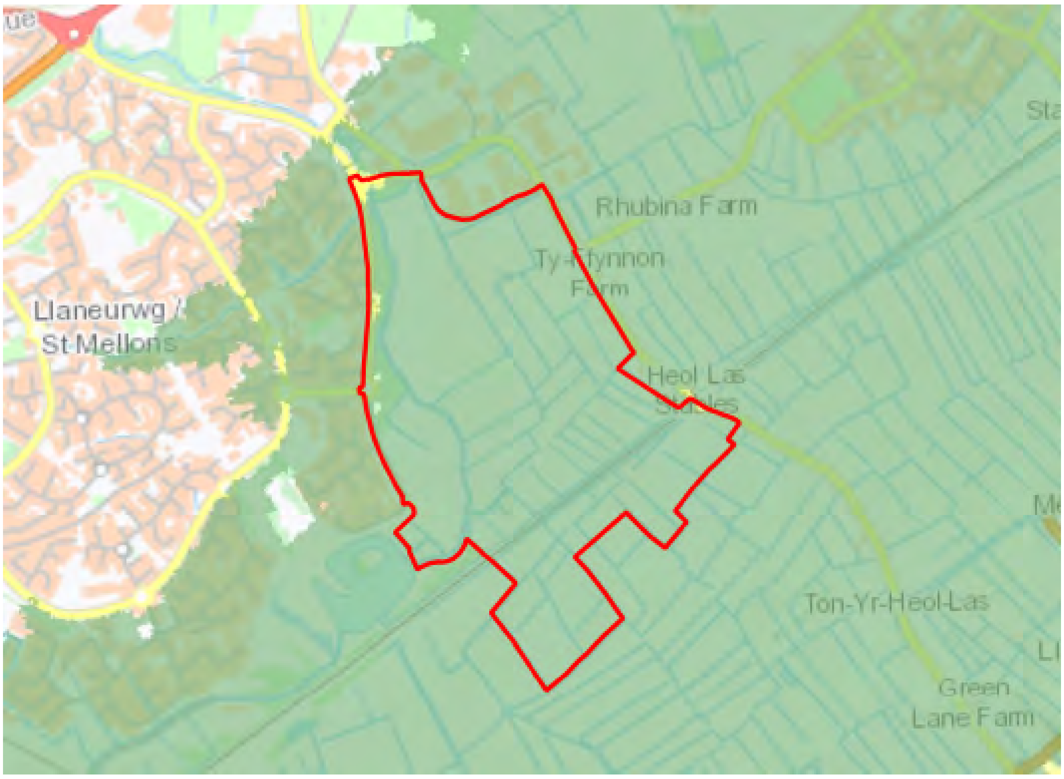


Figure 1: Extract from WG TAN15 DAM for the site. Yellow – Zone B, Green – Zone C1

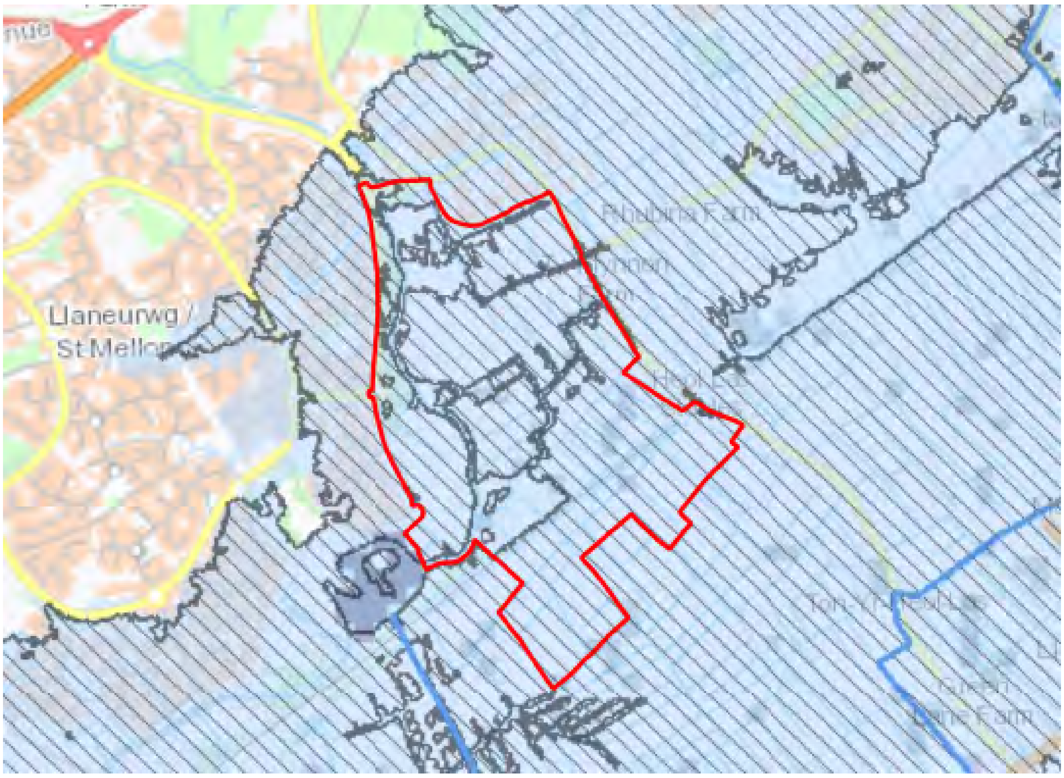


Figure 2: Extract from NRW Flood Risk Maps from River and Seas for the site.

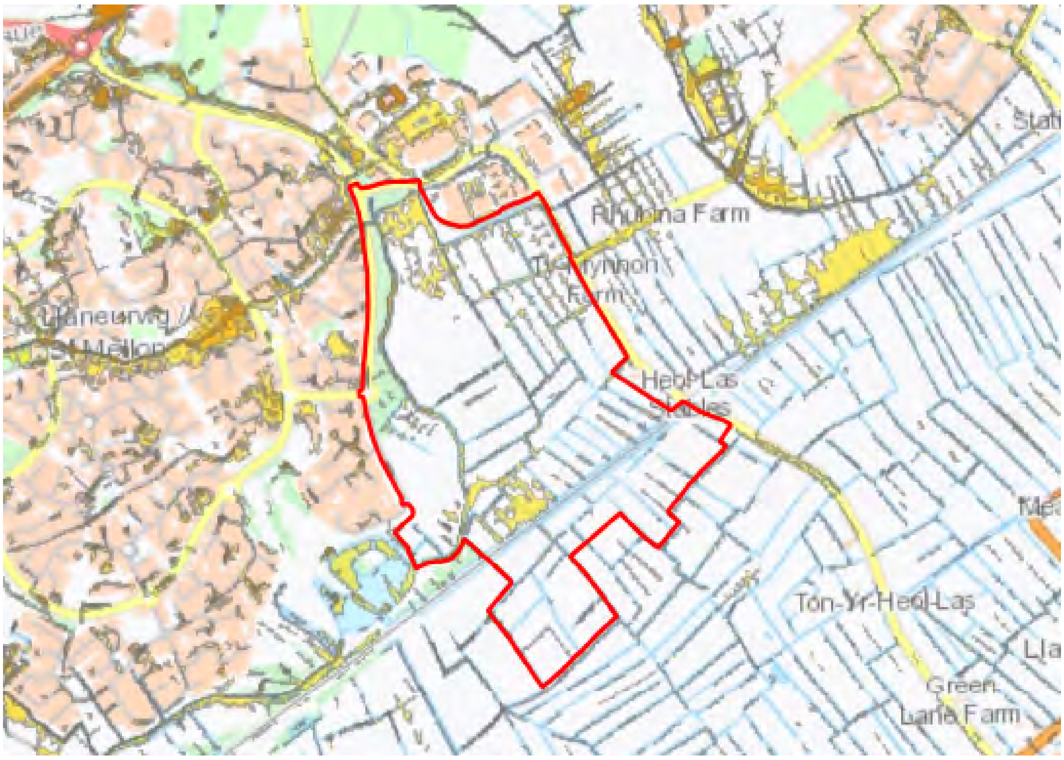


Figure 3: Extract from NRW Surface Water Flood Risk Maps for the site.

Refer to Appendix A6 for the full map extents.

3 Foul Water Drainage

3.1 Introduction

The proposed development will consist of a mix of uses such as retail, restaurant, office and storage/distribution centre spaces. Such uses will consist of welfare facilities and sanitary appliances which will generate domestic foul flows from the proposed development. As such, dedicated new foul drainage networks will be needed to serve the proposed development. As no industrial premises are planned from the proposed development it is considered unlikely that non-domestic foul flows will be generated.

A summary of the strategy to serve the development has been provided in the sections below. Further details of the proposals will be provided at Reserved Matters stage.

3.2 Existing Drainage

From a review of the Dŵr Cymru Welsh Water (DCWW) statutory maps, DCWW assets exists within and near the proposed development.

No public foul or combined gravity sewers exists within the site boundary. DCWW plant record maps do however identify an existing 225mm diameter foul rising main dissecting the northern part of the site from east to west. The foul rising main originates from the DCWW Marshfield pumping station and pumps flows to the west towards St Mellons. Based on discussions with DCWW, a 3m easement exists on either side of the rising main.

The nearest DCWW foul sewers to the proposed development are located to the north and west of the site, along Fortran Road and Cypress Drive respectively. These sewers form part of a wider gravity network that serve St Mellons Business Park and parts of the St Mellons community. The sewer located along Fortran Road is a 225mm diameter gravity sewer that forms part of the St Mellons Business Park network. The sewer along Cypress Drive varies in diameter between 375mm to 450mm and receives flows from the St Mellons Business Park network as well as from parts of the St Mellons community to the west of Cypress Drive. The sewer diameters are to be confirmed upon completion of the various assessments and surveys.

DCWW also confirmed that an existing 1.95m diameter interceptor sewer also exists south of the development, approximately 1.1km south of the railway. It was advised in a recent discussion with DCWW that this was approximately 15m deep with chambers / shafts located along its length. Some of the chambers have a high level connection to receive potential connections, the location and details will need to be verified by various surveys.

The available capacity of the existing DCWW network to receive foul flows from the proposed development is not yet known. A pre-planning enquiry has been sent to determine whether capacity exists to receive foul flows from the proposed development. DCWW are completing a Hydraulic Modelling Assessment (HMA) to confirm whether capacity exist in the existing network to receive foul flows from the proposed development, the points of connection and if any off-site reinforcement works are required to receive flows from the proposed development. DCWW have advised that the points of connection will likely to be to the existing DCWW foul sewer located along Cypress Drive and/or to the existing DCWW Interceptor Sewer located 1.1km south of the railway line.

Considering that the site is greenfield it is unlikely that private foul sewers exists within the site boundary.

For further details of the existing foul drainage details refer to Appendices B1 & B2.

3.3 Proposed Strategy

The proposed development will generate foul flows which will need to be collected and transmitted to the nearest DCWW sewer. It has been estimated that the foul flows generated from the proposed development to be approximately 400m^3/day. Further information of how the foul flows have been estimated are contained in Appendix B3.

Based on initial advice provided by DCWW during the HMA process it is considered that a connection to the existing DCWW foul sewer located along Cypress Drive could be made to serve part or all of the proposed development. However, it’s not yet known whether improvement or reinforcement works are required to the existing network; or is it known, at which phase of development, the need for improvement or reinforcement works will triggered. Such works could include:

- Removal of storm water flows contributing into the existing DCWW foul network which would free some capacity to receive more foul flow into the existing DCWW network; and/or
- Network improvements to the exiting DCWW network.

In the event that neither of the two above options are available, DCWW have advised that an alternative connection location could be made to the DCWW interceptor sewer located south of the railway line.

To transmit the foul flows to the proposed connection location, new foul sewer networks are proposed to transmit foul flows generated from the new development. The new networks will be buried within the roads/road corridors with spurs located at each development plot to receive foul flows from the proposed development. A pumped solution will be required due to the factors outlined as follows:

- limited change in proposed ground level from 6.0m to 7.5m AOD;
- location and extent of the proposed buildings and development plots;
- location of the proposed development in relation to existing foul infrastructure and other constraints such as existing reen network; and

- levels of the existing DCWW foul drainage infrastructure.

It is therefore proposed to allow foul water to flow by gravity from the proposed development to foul pumping stations located at strategic locations across the development.

Foul flows will then be pumped via a series of foul rising mains at an agreed rate to the point of connection, as agreed by DCWW. Full consideration will be given to the location of the foul pumping stations locations to:

1. minimise excavation depths by locating them at low points of the developments;
2. minimising length of drainage sewers;
3. minimise septicity issues;
4. ensure access for maintenance;
5. reduce olfactory and noise pollution; and
6. minimise the visual impact on the development proposals.

Duty and stand-by pumps will also be provided within the pumping stations, with suitable allowances for storage to provide added resilience within the network in an event where all pumps fail. This will allow a suitable period of time for a tanker to empty in line with the requirements of the owner / adopting authority. Further details of the scheme will be submitted for approval at Reserved Matters stage when details of the development are better defined and understood.

The Reserved Matters Applications will include consideration of further sustainability measures such as greywater harvesting for future buildings to minimise the impact on the foul networks.

For further details of the proposed foul water drainage regime refer to Appendix B4.

4 Storm Water Drainage

4.1 Introduction

The proposed development is located on a greenfield site, where a proportion of the water falling on the site during rainfall events is thought to be lost through natural processes such as infiltration, interception and evapotranspiration. The remainder ultimately discharges into the existing reen network.

Developing the site will create impermeable areas, preventing these natural processes and therefore increasing the runoff rate and volume from the site. This section details the stormwater drainage strategy to treat and attenuate these flows, to mitigate the impact as a result of the proposed development.

Further details of the proposals will be provided at Reserved Matters Application stage and in future Full SABS applications. The Pre-SABS Application with the SABS is currently on-going.

4.2 Schedule 3 of the Flood and Water Management Act

Schedule 3 of the Flood and Water Management Act 2010 establishes SuDS Approving Bods (SABs) in local authorities in Wales. Since the 7th January 2019, developments greater than 100m^2 or developments containing more than one building will be required to submit a SAB application. This application requires developers to utilise Sustainable Drainage Systems (SuDS) in their surface water management for a development. As the area of proposed development is approximately 34.4Ha, the development requires a SAB application.

SuDS aim to manage rainfall on site using methods that mimic natural processes, by making use of the landscape and vegetation to control the flow, volume and quality of the surface water runoff. In addition to this, SuDS also provide amenity and biodiversity benefits by providing aesthetically pleasing and natural landscapes, and biodiversity benefits by creating habitats for wildlife and vegetated areas.

The Welsh Government's (WG) "Statutory Standards for Sustainable Drainage Systems" contains six standards, which details the requirements for any SuDS proposed. These sections are as follows:

S1. Runoff destination

S2. Hydraulic control

S3. Water quality

S4. Amenity

S5. Biodiversity

S6. Construction, operation and maintenance

These form a set of principles which must be considered in the design of the SuDS features in order to obtain approval by the SAB. The following sections elaborates on how this is proposed to be achieved across the development proposals.

4.3 SuDS Stormwater Management

4.3.1 S1 - Runoff Destination

The WG's SuDS Standard S1 provides a discharge hierarchy for surface water from developments, as well as exemption criteria for each level that must be met before the next level can be considered. The discharge hierarchy is shown below:

- Level 1: Surface water runoff is collected for use;
- Level 2: Surface water runoff is infiltrated to ground;
- Level 3: Surface water runoff is discharged to a surface water body;
- Level 4: Surface water runoff is discharged to a surface water sewer, highway drain, or another drainage system;
- Level 5: Surface water runoff is discharged to a combined sewer.

The aim of this is to encourage developments to use runoff as a resource and ensure that runoff is sustainably managed to avoid any negative impacts from the development, such as increased flood risk.

4.3.1.1 Collected for Use

The development types, details, layouts and usages have yet to be defined for the site and are currently unknown. As such, rainwater harvesting systems will not be considered at this stage as a means of reducing surface water runoff from the site as the demand for re-use cannot be quantified. Additionally, due to the magnitude of the development, the volume of water generated by collecting surface water runoff generated by impermeable areas of the proposed development will far exceed the amount required for re-use. Therefore, rainwater harvesting is not considered to be a viable solution in isolation and has therefore been discounted at this stage. Consideration will be given to introduce such systems as rainwater harvesting systems, as additional details are known for the proposed development.

4.3.1.2 Infiltrate to Ground

Ground investigation has been undertaken across the site. The investigation has demonstrated that the ground conditions comprise Tidal Flat Deposits overlaying glacial till depositions over mudstone bedrock. The tidal flat deposits comprise of low permeability material and thus are not suitable to support the use of soakaways, especially considering the magnitude of the water to infiltrate into ground. Typical infiltration rates for such ground would be lower than 1×10^{-7} m/s. The Glacial Till and Mudstone bedrock are also generally of a low permeability and would not allow sufficient infiltration. Groundwater monitoring undertaken as part of the ground investigation show groundwater to be present typically approximately 1m below ground level (on average at between 4 and 4.4m Above Ordnance Datum (AOD)).

Extracts from the Ground Investigation report have been included in Appendix C1.

Owing to the size of the proposed development, low permeability of the ground and high groundwater levels, infiltration is not considered as a potential mechanism to transmit storm water flows away from the proposed development in its entirety. However, consideration will be given to implement SuDS features to infiltrate the first 5mm of rainfall and prevent discharge in small return period events. This is discussed further under Standard S2 - Hydraulic Control.

4.3.1.3 Discharge to a Surface Water Body

A reen network exists within and in close proximity of the site as described in Section 2.1 and 2.2. Based on the site topography and low infiltration rates, the existing overland flow path ultimately discharges surface water runoff into the nearest reen network. This is shown by the overland flow analysis in the Appendix A4. Consultation with NRW, who are responsible for controlling and management of the primary reens, have also been undertaken. NRW advised that the existing reen network has been developed over centuries and is highly sensitive. NRW's preference would be to transmit storm flows to Faendre Reen due to the following factors:

- Much greater capacity within Hendre Lake and Faendre Reen.
- A more effective discharge of storm water to the sea from Hendre Lake via Tarwick Reen.
- Relieves the pressure on Green Lane Reen which is close to capacity especially in heavy rainfall events.

A detailed summary of the discussion had with NRW has been included within Appendix A7. The drainage proposal for the development will try to maximise the discharge into Faendre Reen where possible but also maintain the existing flow paths / catchments where this is not possible. To ensure that this is maximised and existing drainage catchments maintained, the proposed development footprint will be raised to a minimum of 6m AOD. This is predominately required for the treatment, transmission and attenuation of surface water runoff generated by the scheme but also forms part of the flood mitigation proposals. Groundwater has been encountered at an approximate depth of 0.6m to 1m below ground level and proposals will be designed so as not to adversely impact the groundwater.

4.3.1.4 Discharge to Surface Water Sewer

From a review of the Dŵr Cymru Welsh Water (DCWW) statutory maps, DCWW assets exists near the proposed development.

No public storm sewers exist within the site boundary. The nearest DCWW storm sewers to the proposed development are located to the north and west of the proposed development, along Fortran Road and Cypress Drive respectively. These sewers form part of a wider gravity network that serve St Mellons Business Park and a number of catchments within the St Mellons community. The sewers discharge into the existing reen networks surrounding the site.

It is likely that additional highway sewers exist along Fortran Road and Cypress Drive as well. These are likely to ultimately discharge storm flows into the existing reen networks however details are unknown.

As discharge to a surface water body can be achieved and there are no existing surface water sewers within the site, this option has not been considered further. Details of the existing drainage network have been included in Appendix B2.

4.3.1.5 Discharge to a Combined Sewer

From a review of the Dŵr Cymru Welsh Water (DCWW) statutory maps, no DCWW combined sewers exists within or near the proposed development.

As discharge to a surface water body can be achieved and there are no existing combined sewers within or in the vicinity of the site, this option has not been considered further. Details of the existing drainage network have been included in Appendix B2.

4.3.1.6 Conclusion

The proposed development is not foreseen to have sufficient demand for non-potable water to make rainwater harvesting in isolation a viable option. Ground investigation results have shown that the ground conditions have insufficient infiltration capability to discharge through infiltration. It is therefore proposed to discharge at an agreed runoff rate to the existing reen networks, which are located in proximity of the development plots.

4.3.2 S2 - Hydraulic Control

The proposed development site is currently a greenfield site used for agricultural purposes. As such, in its existing condition a proportion of rainfall onto the site will be lost though natural processes such as interception, infiltration and evapotranspiration. The remaining volume of water, not lost through these natural processes, flows off the site into the nearest reen network as rainfall runoff. The peak flow rate of the rainfall runoff from the undeveloped site is the Greenfield Runoff Rate (GRR).

Standard S2 requires that:

1. The first 5mm falling on the site is intercepted, therefore producing no runoff for small storm events.
2. The peak flow rate for the 1 in 1-year event for the development is controlled to mitigate negative impacts on the flood risk of the receiving water bodies.

3. The peak flow rates and runoff volume for the 1 in 100-year event for the development is controlled to mitigate negative impacts on the flood risk of the receiving watercourse, with a suitable allowance for climate change (40% for this site).

To meet the interception requirements, appropriately sized SuDS features are required with sufficient retention time to allow the flow to be intercepted. To achieve this, a SuDS management train is proposed. The components of the SuDS management train will vary depending on what parts of the development it is serving and its location within the development footprint. The development will predominately consist of commercial buildings, roads, car parks and public realm areas.

Owing to the size of the development, phasing and different uses, the development has been split to various drainage catchments to replicate the existing catchments. As a consequence, this has had a major influence on the proposed ground profile of the proposed development and dictated a minimum proposed development footprint of 6m AOD for the treatment, transmission and attenuation of surface water runoff generated by the scheme. This has been dictated by:

- reen penning levels,
- proximity of catchment to reen,
- volume/depth of storage, and
- pipe gradients.

A summary of the proposed SuDS components to meet the interception requirements for each of the catchments has been provided in Table 1 below. Refer to drawings HDL-ARP-DN-SW-DRG-ECV-000051 to 000057 included in Appendix C2 for catchment extents and locations.

Table 1: Summary of SuDS Components to meet Interception Requirements

Drainage Catchment	SuDS Components				
	Bioretention Systems / Swales	Swales	Forebay	Dry Ponds	Filter Strip
A	■				
B	■	■			
C, D, E & F	■	■			
G	■				
H	■				
I	■			■	
J, K &L	■				
M	■	■			
N	■		■	■	
O	■			■	
P		■			■
Q	■				
R*					
S	■		■	■	

*Insufficient space to introduce SUDS component – refer to drawing HDL-ARP-DN-SW-DRG-ECV-000056 for further details.

As the development details of the plots are not detailed at this stage, the SuDS components required for interception purposes cannot be fully defined. As such, other SuDS components such as green roofs, raingardens, filter drains and filter strips, as well as additional SuDS components mentioned in Table 1 may be needed to ensure that the proposals still meet interception requirements once the development detail and proposed end use are better understood. The associated details will be defined in subsequent planning and reserved matters applications and associated Full SAB Applications on the same principles as is defined within this Drainage Strategy report.

To meet the interception requirements, each SuDS component outlined above will serve different uses across the proposed development. These are likely to constitute some of the following:

- Roofs: Green roofs, bioretention systems, rain gardens and filter drains.
- Roads and Car Parks: Swales, permeable paving, filter drains, filter strips, bioretention systems and rain gardens.

- Public Realm: Bioretention systems, filter strips, rain gardens and filter drains.

It is proposed that surface water runoff from the planned road corridors located within the drainage catchments, flow into a series of bioretention systems / swales located along the length of the road corridor. A similar approach is proposed for car park located near the south east corner of the site. These bioretention features will provide interception and water quality, amenity and biodiversity benefits. The SuDS Manual recommends bioretention systems / swales to be 2-4% of the impermeable area. A spatial allowance of 3m on either side of the carriageway has been made within the proposals where possible. This is to receive runoff generated from the carriageway, footways and cycleways as well as potentially any adjacent public realm or development plot areas wherever this would be possible.

Figure 4 shows an indicative cross section of a bioretention swale. It is proposed that vegetated side slopes of 1 in 3 are utilised on both sides of the swale.

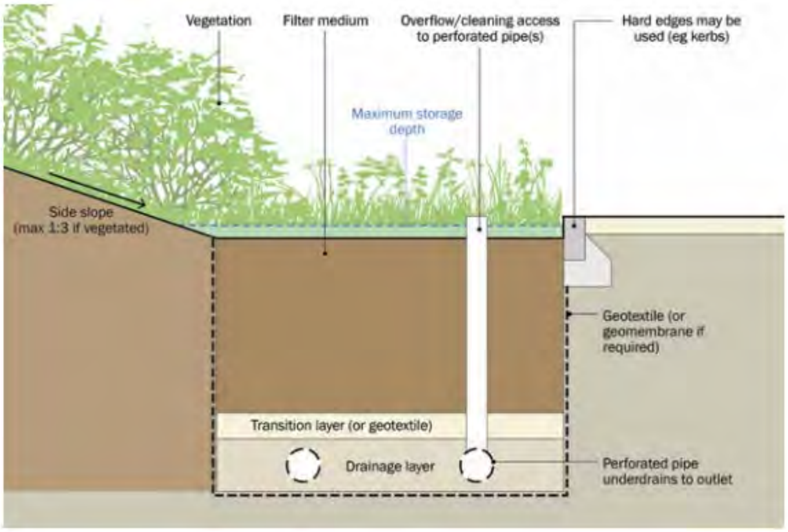


Figure 4: Typical Bioretention Swale (image from SuDS Manual, Figure 15.2)

It is considered that the bioretention systems / swales located along the length of the road corridors and within the car park located near the south east corner of the site will be sufficient to meet the interception requirements for the road corridors and car park that form part of the development proposals. This is on the basis that the impermeable area being more than five times the SuDS vegetated area as per WG standards. Swales and dry ponds are also proposed within some drainage catchments which provide some added interception benefits.

As part of the proposals, a new railway station is also planned. As with the details of the development plots, the details of the station building have not been fully designed to enough detail to demonstrate how the interception requirements could be met. As the scheme is at concept design stage a number of considerations are being made such as:

- Green roof – however this may be limited due to the form and visual appearance of the building as well as other restrictions associated with the maintenance and operations restrictions associated with the rail building;
- Bioretention systems / swales located around the periphery of the building receiving direct surface water runoff from the roofs. Consideration will need to be given to pedestrian and vehicular access
- Open/closed channels directing surface water runoff away from the building to receiving SuDS components located further away from the building. Consideration will need to be given again to pedestrian and vehicular access as well as proposed finished levels.

A similar approach will be used for new buildings, car parking and public realm areas, where strategically placed SuDS features such as bioretention systems / swales, green roofs etc. will be used to intercept flows located to receive storm water runoff from such areas. Other SuDS components exist within the drainage catchments which are not utilised by the road corridors for interception purposes e.g. swales and dry ponds. These could serve the development plots however, it’s not possible to confirm at this stage whether these SuDS components will meet the interception requirements or whether additional features are required locally within the development plot, as the details are unknown at this stage. This will need to be reviewed and confirmed in subsequent planning and reserved matters applications and associated Full SAB Applications.

Once surface water flow has transmitted through the SuDS components within various catchments, it will then discharge to various attenuation features located across the development. Such attenuation features will include either wet ponds, dry ponds or swales. Some attenuation features may also provide interception benefits as well as being attenuation features e.g. swales and dry ponds. Table 2 summarises the type of attenuation features associated with each of the drainage catchments. Refer to drawings included in Appendix B2 for further details.

The attenuation features will either provide storage for the surface water runoff to be discharged at GRR or at the mean annual flood flow (Q_{bar}) for all storm events up to and including the 1 in 100-year return period including an allowance of 40% for climate change. If the GRR is to be adopted then the difference in surface water runoff volume for the 1 in 100-year, 6 hour rainfall event between pre (greenfield) and post development will need to be discharged at 2 l/s/Ha whilst allowing the site to discharge at GRR.

Until it can be demonstrated that the difference in pre and post runoff volume for the 1 in 100-year return period, 6 hour rainfall event can be discharged at 2 l/s/Ha or Q_{bar} whilst allowing the site to discharge at GRR, then hydraulic control measures are proposed to be discharged at Q_{bar} for all storm events up to and including the 1 in 100-year return period including an allowance of 40%.

A hydrological assessment has been undertaken to estimate the GRR and Q_{bar}, refer to Appendix C3 for further details. The assessment estimates the discharge rates as follows:

- 1 in 1 year: 2.4 l/s/Ha

- 1 in 30 year: 4.8 l/s/Ha
- 1 in 100 year: 6.0 l/s/Ha
- Q_{bar}: 2.85 l/s/Ha

Hydraulic models have also been developed to estimate the attenuation storage volumes required for each of the drainage catchment based on limiting the discharge rate to $Q_{bar.}$ Table 2 summarises the attenuation volumes required for each of the drainage catchments. Refer to Appendix C4 for the detailed hydraulic calculations.

Table 2: Summary of Attenuation Features

Drainage Catchment	Attenuation Feature			Discharge Rate (l/s) using Q_{bar}	Estimated Attenuation Volume (m^3) using Q_{bar}
	Dry Pond	Wet Pond	Swale		
A		■		8.1	3,270
B		■	■	11.5	3,820
C			■	0.9	235
D			■	3.0	900
E			■	2.0	625
F			■	1.1	345
G		■	■	4.4	1,830
H		■		7.7	2,525
I	■			4.6	1,575
J		■		4.7	1,560
K		■		2.0	680
L		■		9.1	3,025
M			■	0.6	235
N	■			1.2	465
O	■			0.4	180
P			■	1.8	810
Q*	None			-	-
R*	None			-	-
S	■			3.9	1,830

*Insufficient space to introduce SUDS component – refer to drawing HDL-ARP-DN-SW-DRG-ECV-000056 and 000057 for further details.

If the risk of blockages is considered to be an issue in subsequent design stages, then the allowable discharge rate for each of the catchments may be increased to 5l/s to reduce the risk of blockages.

Any alterations with regards to the hydraulic control will be agreed in subsequent planning and reserved matters applications and associated Full SAB Applications once the details are better developed.

The total attenuation volume proposed for the entire development has been estimated to be approximately 23,900m^3. If it is demonstrated that the site can discharge at GRR and limiting the difference in pre and post development volumes for the 1 in 100-year return period, 6 hours rainfall event to 2 l/s/Ha then the attenuation volume is likely to decrease when compared to the attenuating the flows to Q_{bar}. The pre and post development surface water runoff volume were estimated to be 7,140m^3 and 15,470m^3 respectively.

The development will be phased over a number of years. The extent and timescales are yet to be determined and are likely to change however an indicative phasing diagram has been prepared and included in Appendix C5. The phasing and associated extents will influence the type of attenuation features proposed across the development. The attenuation features may need to be altered or temporary attenuation features provided during the lifetime of the development whilst future phases await to be developed and integrated into the adjacent pre-existing phases. An example of this would be to form temporary dry ponds instead of an attenuation features which are proposed to be integrated into proposed amenity / public realm spaces in future phases where hard landscape / engineered solutions are required. This approach is proposed to minimise and reduce the abortive works and upfront costs, by providing temporary soft solutions to allow for future integration into local amenity space whilst not compromising on the strategy outlined above. Any alterations or temporary measures will be agreed in subsequent planning and reserved matters applications and associated Full SAB Applications once the details are better developed.

No interception measures are provided in Drainage Catchment R and no attenuation provisions are provided in Drainage Catchment Q and R (refer to drawing HDL-ARP-DN-SW-DRG-ECV-000055 and 000056). This is due to the following:

- insufficient space available to introduce such features along corridor due to:
  - existing land profile;
  - proximity of existing trees, reens and vegetation which will have higher amenity, biodiversity and ecological value than if renewed with new SuDS features;
  - proximity of existing residential dwellings; and
  - allowing for spatial allowances for future Cardiff Cycle Superhighway.
- increase in surface water runoff considered to be negligible to extent of works.

It is also advised that the proposed drainage strategy for Catchment N and S (refer to drawing HDL-ARP-DN-SW-DRG-ECV-000051 and 000057) provides significant betterment when compared to the existing situation. This will offset the inability to introduce additional SuDS features within Drainage Catchment Q and R, especially considering the following:

1. alterations to the highway junction proposed are minor; and
2. the catchments are already developed and served by a positive drainage network.

4.3.3 S3 - Water Quality

The water quality standard, S3, requires treatment for surface water runoff to prevent negative impacts on the receiving waterbody in terms of its quality.

The proposed site will include a variety of land uses, namely commercial businesses, roads, car parks and public realm areas. The ‘Simple Index Approach' (SIA) has been used to analyse the proposed land use and SuDS components. The most appropriate land uses as defined by the SIA for the proposed development has been summarised in Table 3 below.

Table 3: Summary of SIA Definition of Land Use

Land Use	SIA Definition
Car Park (> 300 vehicle movements/day)	Non-residential car parking with frequent change (e.g. hospitals, retail)
Car Park (< 300 vehicle movements/day)	Non-residential parking with infrequent change (e.g. schools, offices, < 300 traffic movements a day)
Roads (> 300 vehicle movements/day)	Roads (excluding low traffic roads, highly frequented lorry approaches to industrial estates, trunk roads/motorways)
Roads (< 300 vehicle movements/day)	Low traffic roads (e.g. residential roads and general access roads, < 300 traffic movements/day)
Station Building	Commercial/Industrial roofing: High potential for metal leaching
Other Commercial Buildings	Commercial/Industrial roofing: Low potential for metal leaching
Public Realm	Low traffic roads (e.g. residential roads and general access roads, < 300 traffic movements/day)

Appropriate SuDS features have been selected to ensure anticipated pollutants from the development are sufficiently treated prior to discharge into the downstream receptor via an appropriate treatment train. Soakaway tests have shown that infiltration is not a viable option to discharge surface water from the site, and therefore the minimum treatment processes to meet the water quality requirement for each of the land uses are summarised in Table 4. This may vary between each drainage catchment and may change once development plot proposals are better defined.

Table 4: Summary of Likely Treatment Train / Process

Land Use	Treatment Train / Process *[min. water quality requirement]*
Car Park (> 300 vehicle movements/day)	*bioretention systems → discharge to reen*
Car Park (< 300 vehicle movements/day)*	*bioretention systems → discharge to reen* *swale → discharge to reen*
Roads (> 300 vehicle movements/day)	*bioretention systems → discharge to reen*
Roads (< 300 vehicle movements/day)	*bioretention systems → discharge to reen* *swale → discharge to reen*
Station Building*	*bioretention systems → discharge to reen*
Other Commercial Buildings*	*filter drains → discharge to reen* *bioretention systems → discharge to reen* *swale → discharge to reen*
Public Realm Space*	*bioretention systems → discharge to reen* *swale → discharge to reen*

*Development details unknown treatment train / process may vary in subsequent design stages.

It is considered that the above provides sufficient treatment in accordance with the ‘Simple Index Approach’ for proposed road corridors and car parking areas. The SIA have been included in Appendix C6.

As outlined previously, the development details are not fully defined, and the development plot details are unknown at this stage. As such the details of the SuDS components required for water quality purposes cannot be fully defined. The associated details will be defined in subsequent planning and reserved matters applications and associated Full SAB Applications on the same principles as is defined within this Drainage Strategy report.

Subject to confirmation of the nature of the development within the development plots and the likelihood of storing fuels and oils etc. other guidance documents and standards may also be considered over and above the principles discussed. Such documents could include:

- GPP2: Above ground storage tanks;
- GPP26: Safe storage – drums and intermediate bulk containers;
- Pollution Prevent Guidelines 3 (PPG3); and
- BS EN 858.

4.3.4 S4 – Amenity

The Welsh Standards S4 states that the surface water management systems should maximise amenity benefits.

The SuDS components proposed such as bioretention systems, swales, wet and dry ponds etc. are well suited to urban or built up areas, providing significant amenity benefits through green, vegetated areas adjacent to the proposed development. This will be integrated with the wider landscaping proposals to ensure the proposals maximise opportunities across the development. The wet ponds and swales will add further character to the natural landscape of the area and complement the existing watercourses and ponds in the surrounding landscape.

Refer to landscaping chapter of Design and Access Statement for further details which is an accompanying document of the outline planning application.

4.3.5 S5 - Biodiversity

The Standard S5 requires that surface water management systems also maximise biodiversity benefits.

Bioretention systems / swales provide and dry ponds a significant contribution to biodiversity and quality habitats for wildlife. Proposed vegetation will be designed to support local diversity through liaison between landscape architects, ecologists and horticultural/arboricultural experts where necessary.

The ponds will provide a wet habitat for amphibians, expanding the habitat at the edge of the existing watercourse and thereby creating a larger ecological area. The treatment train / process will seek to treat runoff prior to entering the pond to ensure sufficient water quality levels to promote biodiversity.

Restricting the flows leaving the site will protect watercourses downstream from erosion and maintain the existing ecological environment.

Refer to landscaping chapter of Design and Access Statement for further details which is an accompanying document of the outline planning application.

4.3.6 S6 - Construction, Operation and Maintenance

Standard S6 requires that the proposed surface water drainage systems are designed such that they can be constructed, operated and maintained easily, safely and cost effectively for the whole design life of the systems. They should also aim to minimise the use of natural resources and embedded carbon.

These aspects will be considered through the design of the drainage system. A SuDS Management Plan will be developed to determine how the proposed SuDS features can be effectively and efficiently managed and operated with associated ongoing costs for maintenance included where possible. The SuDS management plan will be submitted as part of the full SAB application.

Subject to agreement between the SAB and Cardiff Parkway Development Ltd the SuDS features which serve the more than one plot/property could be adopted by the SAB, who would then take responsibility of repair and maintenance of the SuDS features proposed included within the Hendre Lakes proposals if that were to be the case.

The contractor will prepare a construction environmental management plan (CEMP) to manage runoff (including silt) and to restrict the temporary runoff to the agreed discharge rate. Such measures have been outlined in the Water Resources chapter of the environmental impact assessment and CEMP accompanying the outline planning application.

5 Conclusion

A drainage strategy has been prepared for the surface water and foul water drainage to serve the Hendre Lakes proposals. The strategy is currently being reviewed by the SAB through the Pre-SABS Application process.

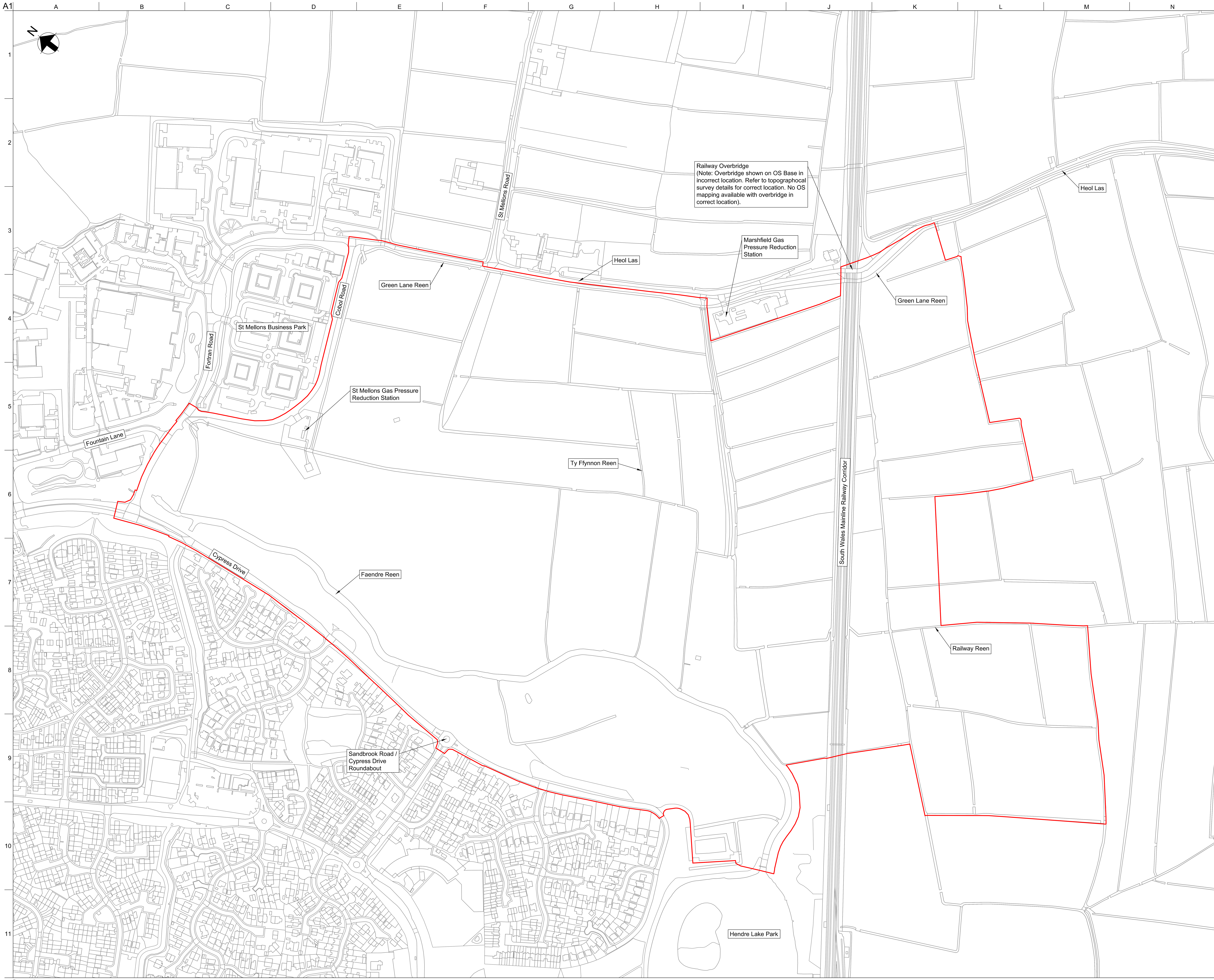
The requirements for the foul drainage connections are unknown, until DCWW finalise the HMA. However, preliminary discussions with DCWW have advised that a point of connection could either be made to existing DCWW infrastructure located within Cypress Drive or potentially 1.1km south of the railway line. The foul flows generated from the development will need to be pumped to the proposed connection locations.

The principles of the storm drainage strategy have been considered and discussed in detail. It is proposed that surface water runoff generated from the impermeable areas of the site discharge to various SuDS features strategically located across the proposed development. Primary road corridors and car park planned to the south east of the development is proposed to discharge to bioretention system / swales adjacent to the road corridor or car parking bays where the first 5mm of rainfall will be treated and intercepted. In larger storm events, the SuDS features will treat runoff and convey flows to attenuation features such as wet and dry ponds and swales located across the development before discharging to the existing reen network. This will be at either Q_{bar} or at GRR, if it can be demonstrated that the difference in pre and post runoff volume for the 1 in 100-year return period, 6-hour rainfall event can be discharged at 2 l/s/Ha.

Appendix A

The Site

A1 Site Location Plan



Notes

1. Do not scale from this drawing.
2. All dimensions are in metres unless stated otherwise.
3. The details shown on this drawing are based on a schematic design produced for the outline planning application. The details will need to be reviewed and revised during subsequent design stages.

Legend

Site Boundary

Issue	Date	By	Chkd	Appd
I0	01/05/20	DS	SW	JS
	Issued for Information			

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Client
Cardiff Parkway Developments Ltd

Project Title
Hendre Lakes

Drawing Title
Site Location Plan

Scale at A1: 1:2500
Role: Civils
Suitability: For Information
Job No: 252199-00
Rev: I0
Drawing No: HDL-ARP-ZZ-SW-DRG-ECV-000001

Do not scale

A2 NRW Reen Network Plans


Board
Caldicot & Wentlooge Levels
Site
Drainage and Water Level Management
Key
IDB Boundary
CWL Reens
Flow Direction
EA Reens
CWL Sluices
Tidal Flaps
Church Reen
Little Penning Reen
Penning Reen
Ty Mawr Reen
Marshfield
Little Greenlane Reen
Wood Ditch Reen
Wellfield West Reen
Wellfield East Reen
Summerway Reen
Horsecroft Reen
Wentlooge Level
Faendre Ext
Faendre Winter Sewer
Green Lane Branch
Faendre Reen
Blackwater Reen
Peterstone Reen
Broadway Reen
Llaneirwg/ St Mellons
Ty-Fflynon Reen
Greenlane Reen
Cross Reen
Rhosog Fawr Reen
Railway Reen
Fen Eliffant Reen
Walwyn Place Reen
Hendre Reen
Trowbridge
St Mellons Reen
Tarwick Reen
Peterstone Watercourse
Six Bells Reen
Pil-du Reen
Rhosog Fawr Branch Reen
Rhosog Fawr West Reen
Newlands Reen
Ty-Du Reen
Rhosog Fawr Reen
Back Ditch, Tabbs Gout to Peterstone Gout
Rhosog Fawr East Reen
Wentlooge Levels

WATER LEVELS

GREEN LANE

Preferred and actual summer penning level – 4.400

Preferred and actual winter penning level - 4.050

TY-FFYNNON

Preferred summer penning level – 4.500

Actual summer penning level - 4.400

Preferred winter penning level - 4.200

Actual winter penning level - 4.050

N.B - The discrepancy between act & pref levels is due to sluice W28 being in an unfit condition to pen back water. However, sluice W28 is due for refurbishment next year which will mean being able to pen water at the preferred level.

Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Legend

Notes

0.4 0 0.21 0.4 Kilometers

British_National_Grid

WATER LEVELS – SOUTH OF RAILWAY LINE

GREEN LANE REEN

Summer Penning Levels (SPL) – Preferred (book levels) – 3.900

Actual level – 3.950

Winter Penning Levels (WPL) – Preferred & Actual – 3.350

RAILWAY & St MELLONS REENS

Summer Penning Levels (SPL) – Actual & Preferred – 4.150

Winter penning Levels (WPL) – Actual & Preferred – 3.800

Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Legend

Notes

0.3 0 0.13 0.3 Kilometers

British_National_Grid

WATER LEVELS

Faendre Reen

Summer Penning Level Preferred – 4.800

Summer Penning Level Actual - 4.590

Winter Penning Level preferred & actual – 4.000

N.B – Approximately 15 - 20 years ago a decision was made to reduce the SPL in Faendre Reen due to the rapid expansion of St. Mellons housing estate. The water entering the system via run off from the roofs and roads is extremely rapid so extra attenuation was needed to cope with sudden and high summer rainfall events. The reduction of 210mm represents the approximate height of one standard sized penning board.

Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Legend

Notes

0.5 0 0.25 0.5 Kilometers

British_National_Grid

WATER LEVELS – SOUTH OF RAILWAY LINE

GREEN LANE REEN

Summer Penning Levels (SPL) – Preferred (book levels) – 3.900

Actual level – 3.950

Winter Penning Levels (WPL) – Preferred & Actual – 3.350

RAILWAY & St MELLONS REENS

Summer Penning Levels (SPL) – Actual & Preferred – 4.150

Winter penning Levels (WPL) – Actual & Preferred – 3.800

Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Legend

Notes

0.5 0 0.25 0.5 Kilometers

British_National_Grid

A3 Existing Ground Profile Details

Legend

Site Boundary

Extent of Topographical Survey

Notes

1. Do not scale from this drawing.

2. All dimensions are in metres unless stated otherwise.

3. The details shown on this drawing are based on a schematic design produced for the outline planning application. The details will need to be reviewed and revised during subsequent design stages.

4. The topographical survey details shown within the topographical survey boundary has been provided by Cardiff Parkway Development Ltd on 18/01/2018 from a survey completed by Landmark Surveys (Wales) Ltd in January 2018. The level information shown outside the topographical survey boundary is based on LiDAR information received 03/01/2020. No responsibility can be given for the accuracy of these surveys.

5. All levels are above ordnance datumn (m AOD).

Issue	Date	By	Chkd	Appd
I0	01/05/20	DS	SW	JS
	Issued for Information			

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Project Title
Hendre Lakes

Drawing Title
Existing Ground Profile
Sheet 1 of 3

Scale at A1: 1:1250
Role: Infrastructure
Suitability: For Information
Job No: 252199-00
Rev: I0
Drawing No: HDL-ARP-SU-SW-DRG-ECV-000011

Do not scale

Legend

Site Boundary

Extent of Topographical Survey

Notes

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Drawing Title
Existing Ground Profile
Sheet 2 of 3

Scale at A1 1:1250 | Role Infrastructure

Suitability For Information

Job No **252199-00** | Rev **I0**

Drawing No
HDL-ARP-SU-SW-DRG-ECV-000012

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Legend

- Site Boundary
- Extent of Topographical Survey

Notes

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3. The details shown on this drawing are based on a schematic design produced for the outline planning application. The details will need to be reviewed and revised during subsequent design stages.

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Drawing Title
Existing Ground Profile
Sheet 3 of 3

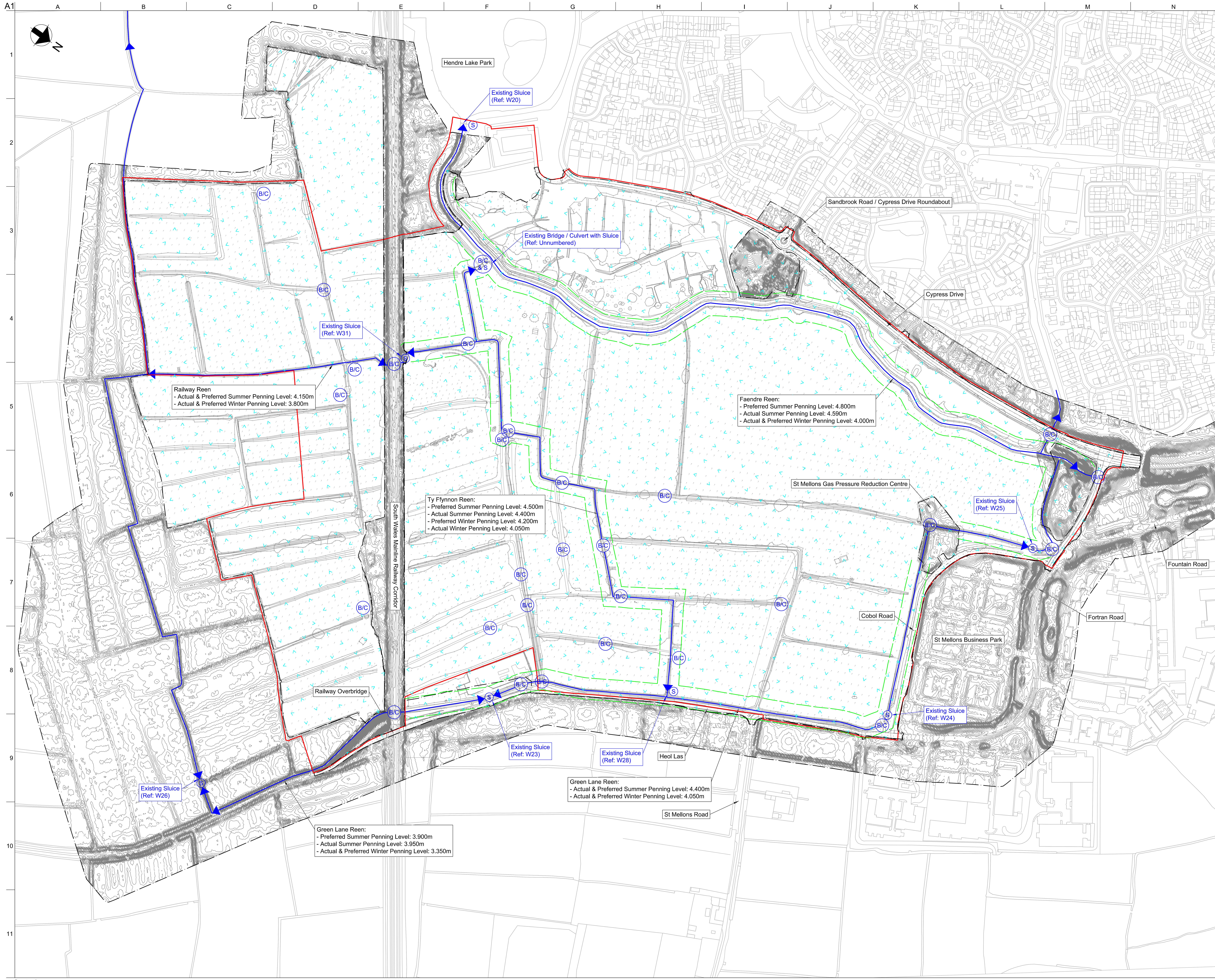
Scale at A1: 1:1250
Role: Infrastructure
Suitability: For Information

Job No: **252199-00**
Rev: **I0**

Drawing No
HDL-ARP-SU-SW-DRG-ECV-000013

Do not scale

A4 Existing Reen Details and Overland Flow Routes



Legend

- Site Boundary
- Topographical Survey Boundary
- Existing Sluice
- Existing Bridge / Culvert
- Existing Primary Reen
- 12.5m Reen Offset
- Overland Flow Route

Notes

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3. The details shown on this drawing are based on a schematic design produced for the outline planning application. The details will need to be reviewed and revised during subsequent design stages.
4. The topographical survey details shown within the topographical survey boundary has been provided by Cardiff Parkway Development Ltd on 18/01/2018 from a survey completed by Landmark Surveys (Wales) Ltd in January 2018. The level information shown outside the topographical survey boundary is based on LiDAR information received 03/01/2020. No responsibility can be given for the accuracy of these surveys.
5. All levels are above ordnance datum (m AOD).
6. The reen penning levels and references obtained from discussions and correspondence received from NRW on 16/10/2019 and 18/10/2019 respectively.

Issue	Date	By	Chkd	Appd
I0	01/05/20	DS	SW	JS
Issued for Information				

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Hendre Lakes

Drawing Title
Existing reen Details and Overland Flow Routes

Scale at A1: 1:2500
Role: Infrastructure
Suitability: For Information

Job No: 252199-00
Rev: I0

Drawing No
HDL-ARP-ZZ-SW-DRG-ECV-000024

Do not scale

A5 FCA

Hendre Lakes – Flood Consequence Assessment

June 2020

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Revision History

Revision Ref / Date	Amendments	Issued to
3rd April 2020	First issue	John Smith
20th April 2020	Second issue	John Smith
23rd June 2020	Third issue	John Smith

Contract

This report describes work commissioned by John Smith, on behalf of Arup, by an email dated 11th February 2020. Paul Redbourne and Amy Evans of JBA Consulting carried out this work.

Prepared by

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Reviewed by................................. George Baker BEng AIEMA CEnv IEng MCIWEM C.WEM

Technical Director

Purpose

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JBA Consulting has no liability regarding the use of this report except to Arup.

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Contents

List of Figures

List of Tables

1 Introduction

1.1 Terms of Reference

JBA Consulting (JBA) were commissioned by Arup to undertake a Flood Consequence Assessment (FCA) in support of a proposed development, Cardiff Hendre Lakes. The proposals are for a new business district of up to 90,000sqm of campus style employment floor space, together with the construction of a new transport interchange (including a train station) and ancillary development.

The site is cross boundary with the majority of the proposed development located within Cardiff, however small parts of the site are located within Newport. This FCA has therefore been prepared in support of an Outline Planning Application (OPA) to Cardiff Council as well as in support of three separate Full Planning Applications (FPAs) to Newport City Council for works along the eastern boundary of the site.

1.2 FCA Requirements

This FCA follows Welsh Government guidance on development and flood risk set out in Technical Advice Note 15: Development and Flood Risk (TAN15). Where appropriate, the following aspects of flood risk will be addressed in all planning applications over its expected lifetime in flood risk areas:

- The likely mechanisms of flooding
- The likely source of flooding
- The depths of flooding through the site
- The speed of inundation of the site
- The rate of rise of flood water through the site
- Velocities of floodwater across the site
- Overland flow routes
- The effect of access and egress and infrastructure, for example public sewer outfalls, combined sewer outflows, surface water sewers and effluent discharge pipes from wastewater treatment works
- The impacts of the development in terms of flood risk on neighbouring properties and elsewhere on the floodplain

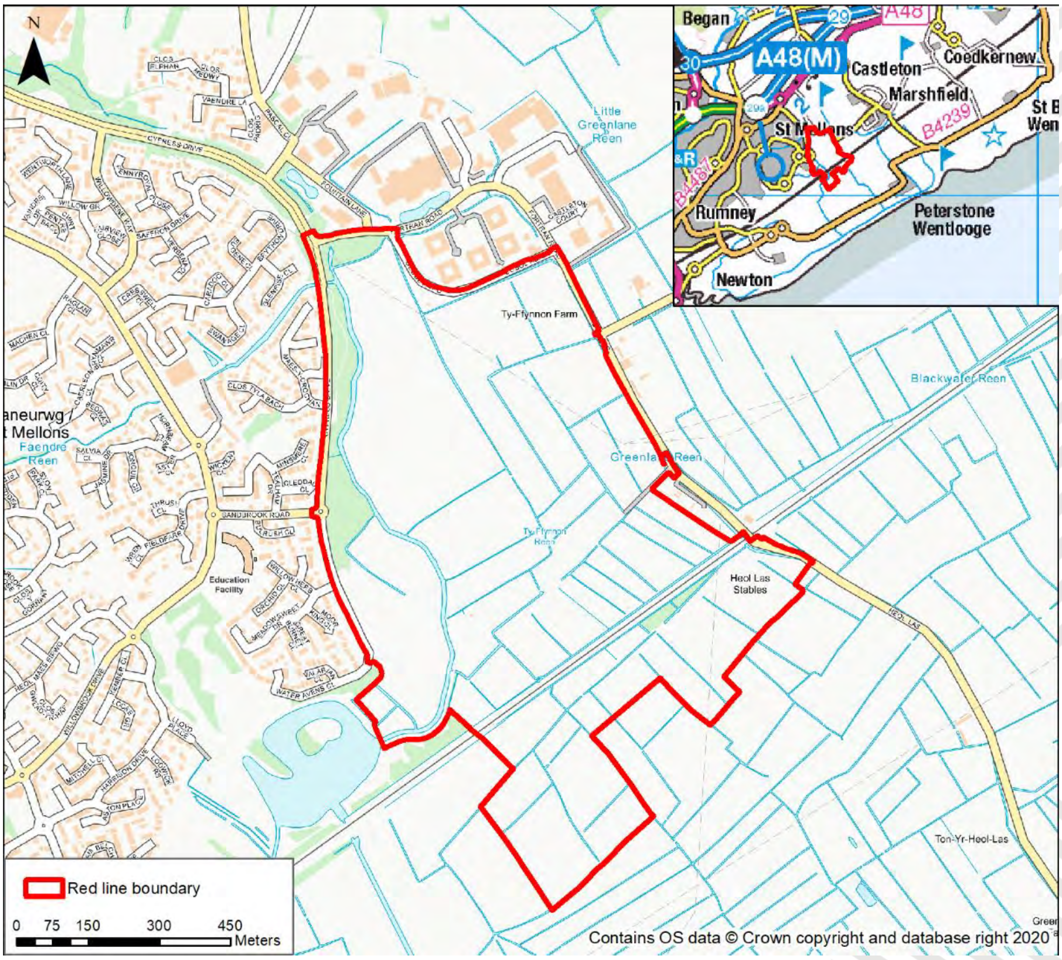
2 Site Description

2.1 Site Location

The proposal is for a large mixed-use development in the St Mellon's area of Cardiff. The site currently consists of grasslands and is surrounded by housing to the west, St Mellons Business Park to the north and farmland to the south and east. The main railway line from Newport to Cardiff runs along the southern edge of the site. The Faendre Reen flows in a southerly direction on the western edge of the proposed development, with the Hendre Lake lying 200m west of the development. The area to the south of the railway may also be used to provide compensatory ecological improvements and flood risk mitigation. The location of the development site is described and shown below in Table 2-1. Appendix A contains the overall site boundary.

Table 2-1 Site Summary

Site name	St Mellons
Site area	Approx. 46 hectares
Existing land use	Farmland
Purpose of development	Commercial, train station
Postcode	(NEAREST) CF3 0YY
OS NGR	ST 25097 81224
Local Planning Authorities	Cardiff Council
Lead Local Flood Authority	Cardiff Council



2.2 Existing land use and site topography

The site currently consists of grassland with a network of artificial drainage reens running through the fields. The main reen on site, the Faendre Reen, flows in a southerly direction along the western boundary of the site and in to Hendre Lake, just west of the development site. The Greenlane Reen flows across the northern and eastern boundary of the site. The Ty-Ffynnon Reen flows from east to west in the southern area of the site. The locations of the main reens on site are shown in Figure 2-1.

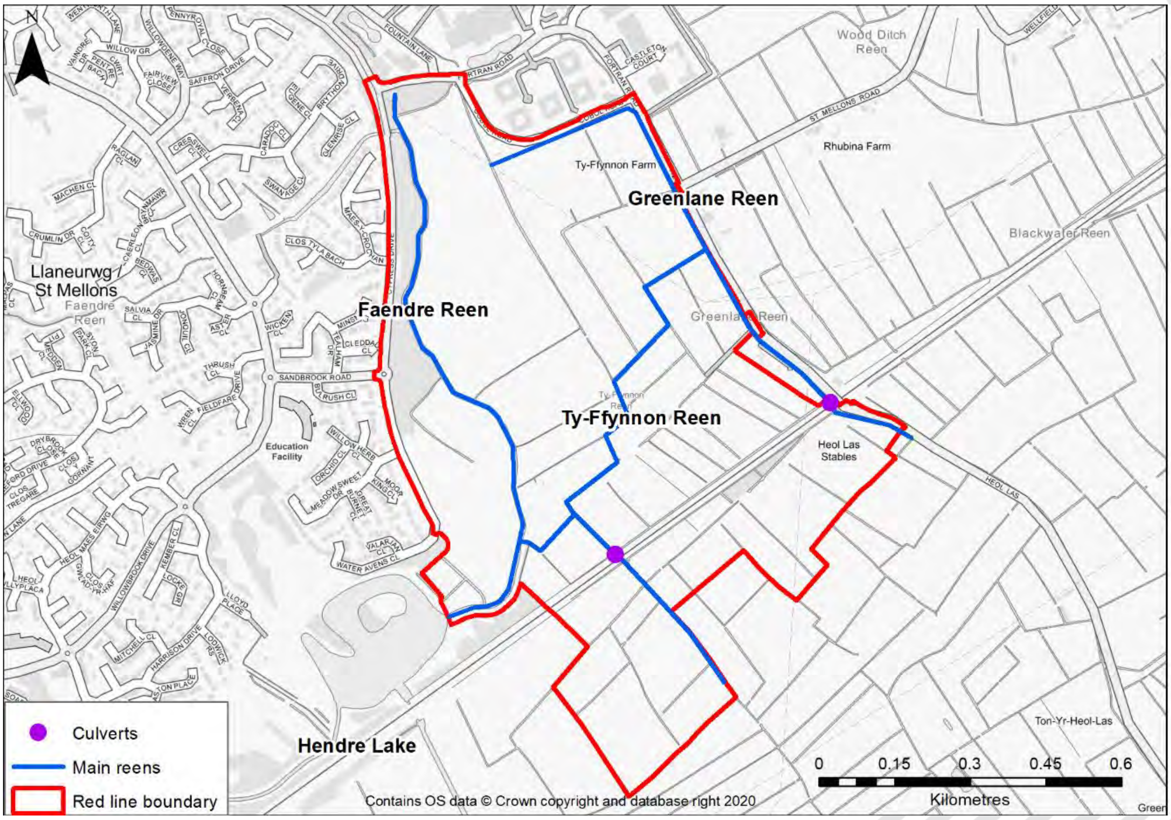


Figure 2-1 Main reens and culverts within the development site

The site is currently managed by multiple land owners. The primary reen network is managed by Natural Resources Wales (NRW). The secondary reen network and field ditches are managed by each land owner.

The site was reclaimed from marshland and inter-tidal areas and it provides a wide variety of semi-natural habitats for rare species and fertile land for grazing. The main structure onsite is the railway line along the southern boundary of the site at 6.5mAOD. Additionally, there are two culverts beneath the railway line, which convey the Ty-Ffynnon and Greenlane Reens south.

The site is also constrained by several major utility assets, including National Grid pylons and Wales and West gas pipelines.

Topographically, the site is relatively flat with ground levels ranging from 4.8 to 5.4mAOD (Figure 2-2). There is a very slight slope from the west to east of the site. The LiDAR shows the prevalence of artificial drainage systems in the areas, ranging from major reens to shallow ridge and farrow field drainage.

The site is situated on the Wentlooge Levels, part of the Caldicot & Wentlooge Drainage District. Consequently, land drainage is actively managed by NRW in their function as the Internal Drainage Board (IDB). NRW's primary role with regard to drainage districts is to manage water levels and reduce flood risk through the management and maintenance of drainage channels, ordinary watercourses, pumping stations and control structures.

NRW are also responsible for the significant coastal flood defences that protect the Wentlooge Levels from coastal flooding. These flood defences are largely formed of large embankments and rock revetment along the Severn Estuary; approximately 1.5km southeast of the site.

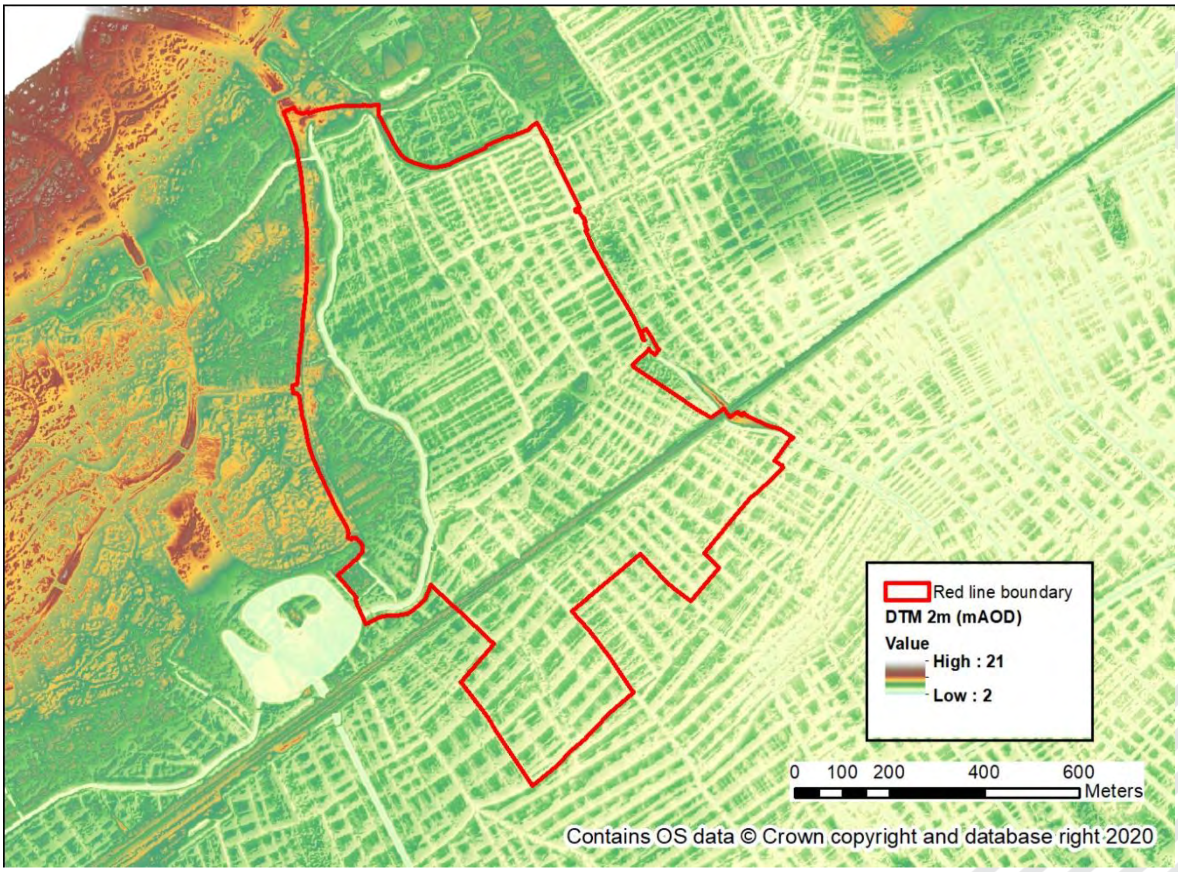


Figure 2-2 Topography on the development site

2.3 Soils and geology

The geology of Britain map viewer from the British Geological Survey (BGS)[1] shows that the area's geology forms part of the St Maughan's Formation, which consists of argillaceous rocks and sandstone formed 393 to 419 million years ago in the Devonian Period. The Cranfield Landis Soilscape viewer[2] describes the site's soil as loamy and clayey typical of coastal flats with naturally high groundwater. The site is naturally wet so a robust flood risk and surface water management approach will be crucial.

2.4 Development proposal

The proposed development is for the construction of a new train station and areas of commercial development. The current development masterplan is shown in Figure 2-3 and Appendix B, a detailed design masterplan has not yet been agreed.

[1] Geology of Britain Viewer. LINK

[2] Cranfield Soil Scapes Viewer. LINK

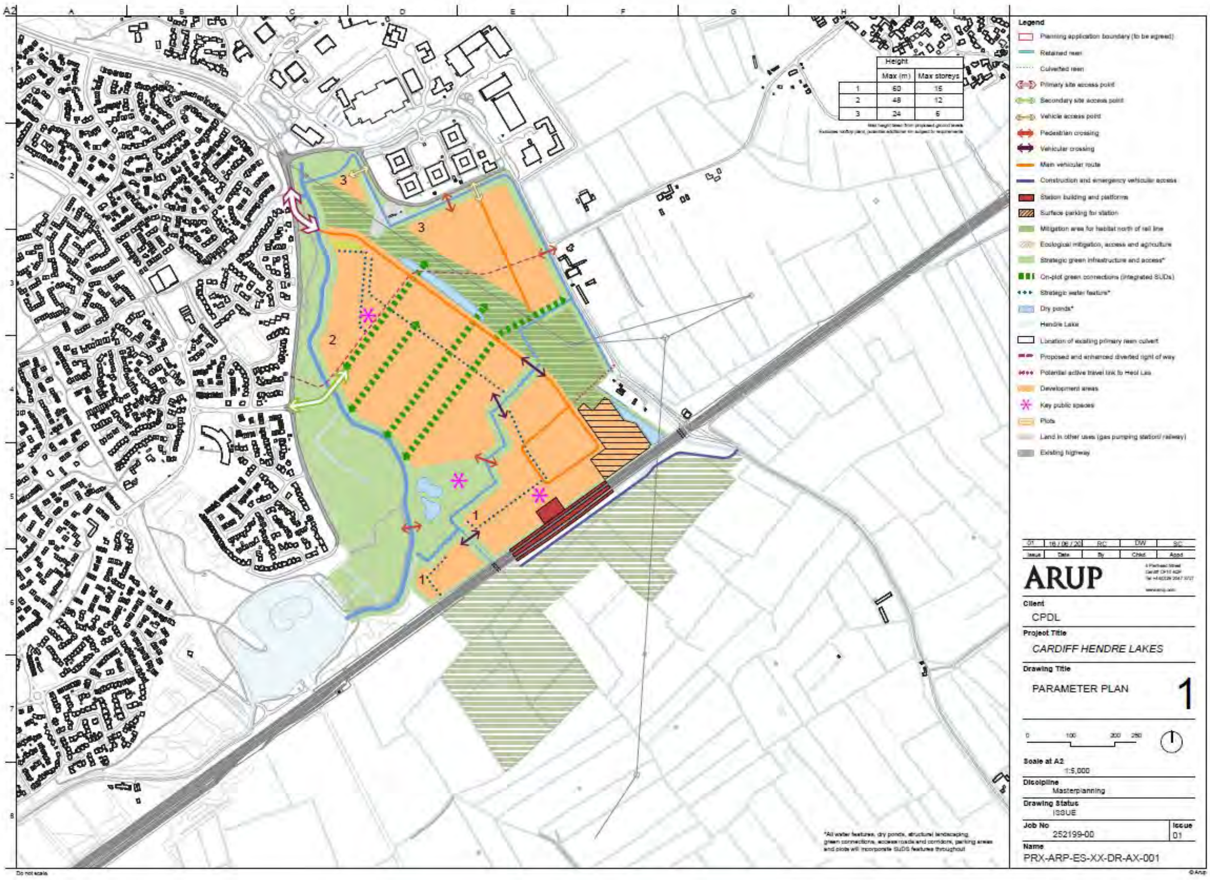


Figure 2-3 Development masterplan

2.5 Review of existing flood risk data

The latest available information on flood risk at the site, published by Natural Resources Wales (NRW) is summarised in Table 2-2 and is discussed in further detail below.

Table 2-2 Summary of Flood Risk

Source of Flooding	Onsite Presence	Description
Tidal and Fluvial	✓ (see section 2.7)	The site is located within NRW Flood Zone 3 on account of its tidal risk.
Surface Water	✓ (see section 2.8)	The site has a low risk of flooding from surface water.
Groundwater	× (see section 2.9)	The site is at a low risk of flooding from groundwater.
Reservoirs	×	The site is not considered to be at risk of flooding from reservoirs.
Sewers	×	There is no evidence to suggest that the site is at risk of flooding from sewers.

2.6 Historical Flooding

The site boundary has been compared to NRW's Historic Flood Map[3], this flood map implies that there has been no recorded flooding to the site. In addition, no specific mention is made within the Cardiff Council Flood Risk Management Plan (FRMP) of any historical flooding across the proposed development site. The FRMP considers that there is no significant risk of flooding from the reens within the Cardiff Council boundary.

2.7 Existing Flood Zone mapping (tidal and fluvial risk)

NRW's flood mapping indicates that the current site is located within Flood Zone 3, as shown in Figure 2-4. This suggests that there is a 0.5% Annual Exceedance Probability (AEP) of the site flooding from the sea in any year.

The Flood Zones describe the predicted flood risk without considering the protection provided by flood defences. However, the Flood Map also identifies Areas Benefiting from flood Defences (ABD), and such a designation is shown to cover a large proportion of the site and surrounding areas. Consequently, further interrogation of the hydraulic modelling which informs the Flood Zone map is required to fully appreciate the site's actual flood risk.

Fluvial flood risk is shown as the areas not benefiting from the flood defences in Figure 2-4. However, as part of the Cardiff SFCA fluvial flood risk was modelled in more detail in 2012[4] with more detail provided in Section 6.

The hydraulic modelling completed to support a detailed assessment of flood risk is described in Section 5 and 6.

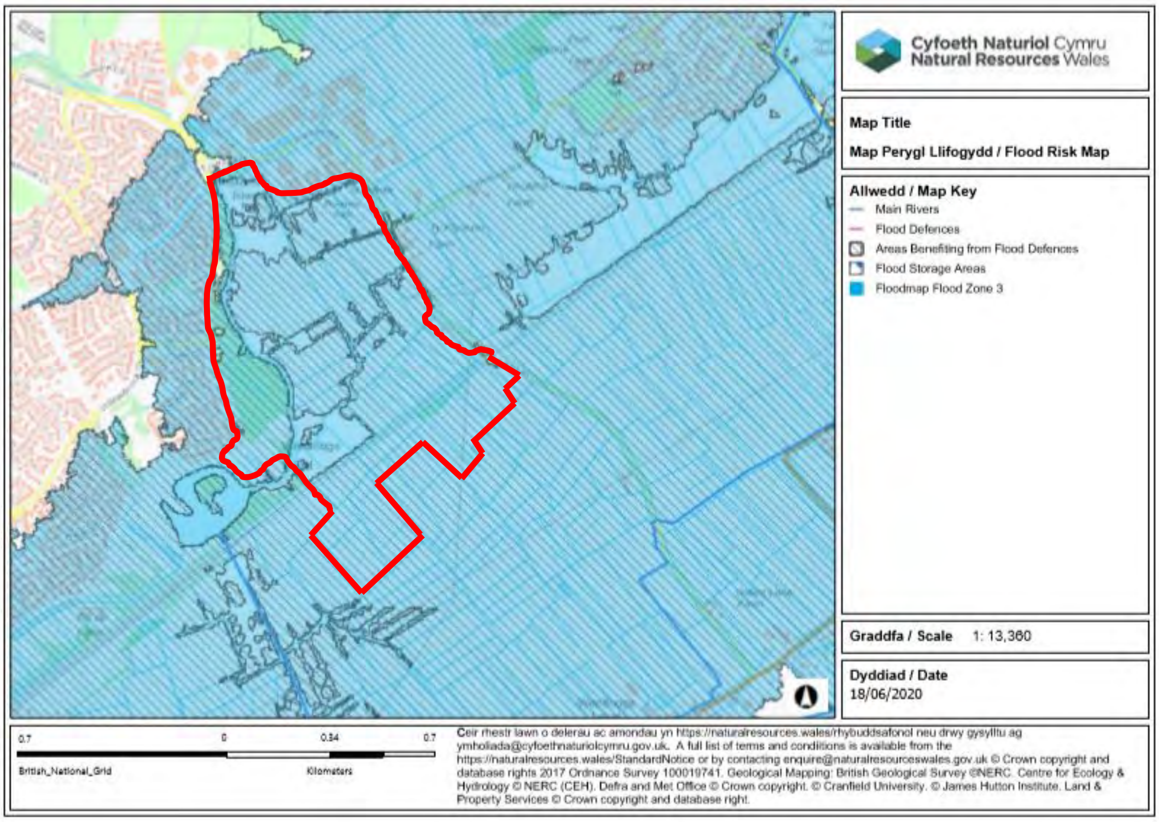


Figure 2-4 NRW Flood Map

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[3] NRW Historic Flood Map. LINK

[4] Cardiff SFCA Addendum to Stage 3 Preliminary Site Assessments – Area A. Atkins, 2012

2.8 Surface water flood risk

Surface water flooding occurs when rain falling on saturated ground flows overland, following the local topography. Surface water flooding and subsequent overland flow can also originate from surcharging blocked sewers or drains. Depending on the return period, sewer flooding can also occur from overloading of sewers due to their capacity being exceeded by large amounts of surface water. This typically occurs in events exceeding the 1 in 30 year. Overland flow can therefore pose a risk to both the development site and surrounding land. Overland flows may originate from the site itself or adjoining land at a higher elevation from which flow migrates onto the development area.

NRW's Flood Map for Surface Water (FMfSW) indicates that the site is at a very low to low risk of surface water flooding, as shown in Figure 2-5. Areas of low surface water flood risk follow the historical reen network, with areas in the north and south of the site showing the widest areas of surface water flooding.

2.6 Historical Flooding

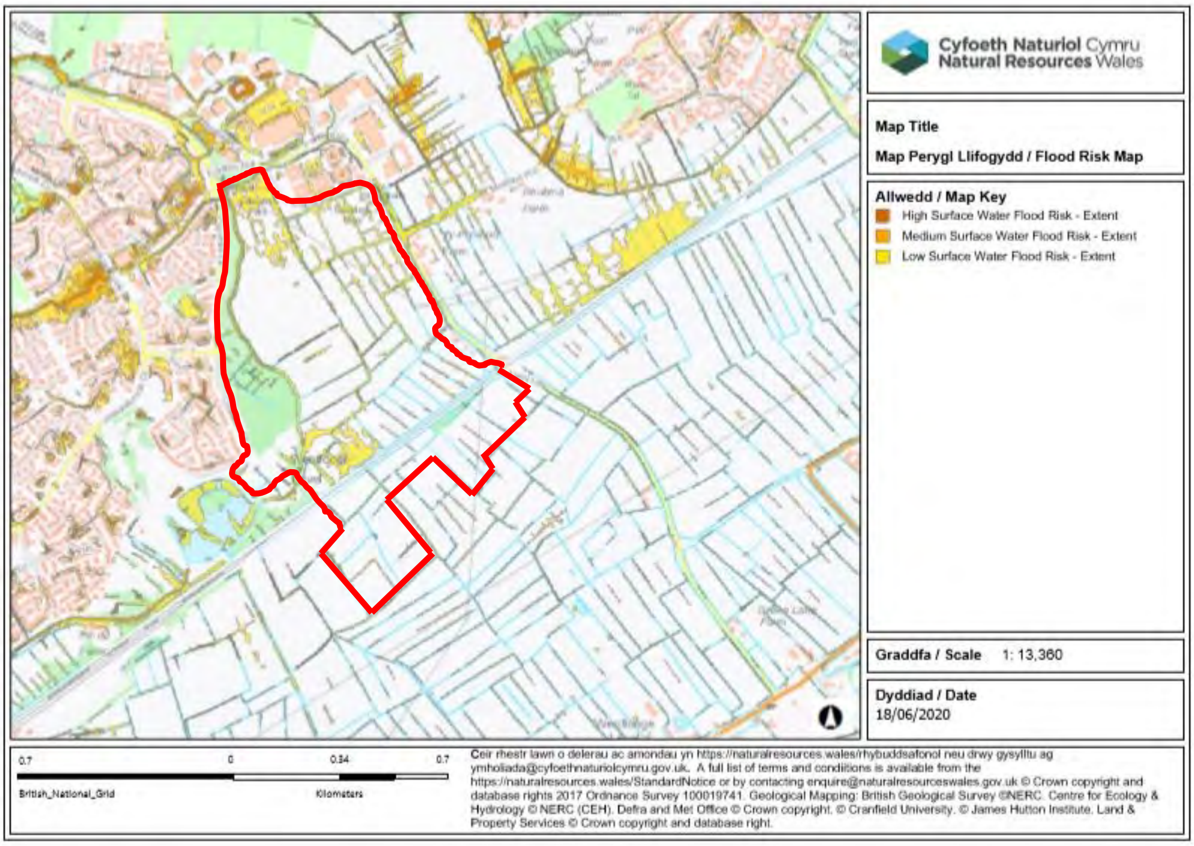

Figure 2-5 Surface water flood risk

2.9 Groundwater Flood Risk

Groundwater flooding is caused by unusually high groundwater levels. It occurs as excess water emerging at the ground surface, or within manmade structures such as basements. Groundwater flooding tends to be more persistent than surface water flooding, in some cases lasting for weeks or months and can result in damage to property. This risk of groundwater flooding depends on the nature of the geological strata underlying the site, as well as on the local topography.

Section 2.3 highlights that the site has a naturally high ground water level and the site could be suspectable to ground water flooding. However, The Cardiff Council Flood Risk Management Plan 2015[5] states that there is *"no information on historic groundwater flooding which suggests that the risk of groundwater flooding is low in Cardiff".*

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[5] Cardiff Flood Risk Management Plan (2015): LINK

3 Planning Policy and Flood Risk

3.1 Planning Context

TAN-15 was introduced in 2004 by the Welsh Assembly Government. It is technical guidance related to development planning and flood risk using a sequential characterisation of risk based on the Welsh Government's Development and Flood Risk Advice Map (DAM). Its initial requirement is to identify the flood zones and vulnerability classification relevant to the proposed development, based on an assessment of current and future conditions.

TAN-15 assigns one of three flood risk vulnerability classifications to a development as shown in Table 3-1. The proposed development at St Mellons is classed as commercial and transport infrastructure. Consequently, the development is classified as *less vulnerable* development with a development lifetime of 75 years in-line with Welsh Government guidance[6].

Table 3-1 Development categories defined by TAN15

Development category	Types
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.

3.2 DAM Zoning and Vulnerability Classification

Figure 3-1 shows that the proposed development site falls in Zone C1 of the DAM. The DAM is used to trigger different planning actions based on a precautionary assessment of flood risk. Zone C1 is described as areas of the floodplain which are developed and served by significant infrastructure, including flood defences. The site benefits from the protection provided by NRW’s Wentlooge Levels Coastal Flood Defences.

Less vulnerable development can take place within C1 subject to the application of the Justification Test, including a demonstration of the acceptability of the flood consequences.

[6] Welsh Government (2017) Adapting to Climate Change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales. LINK

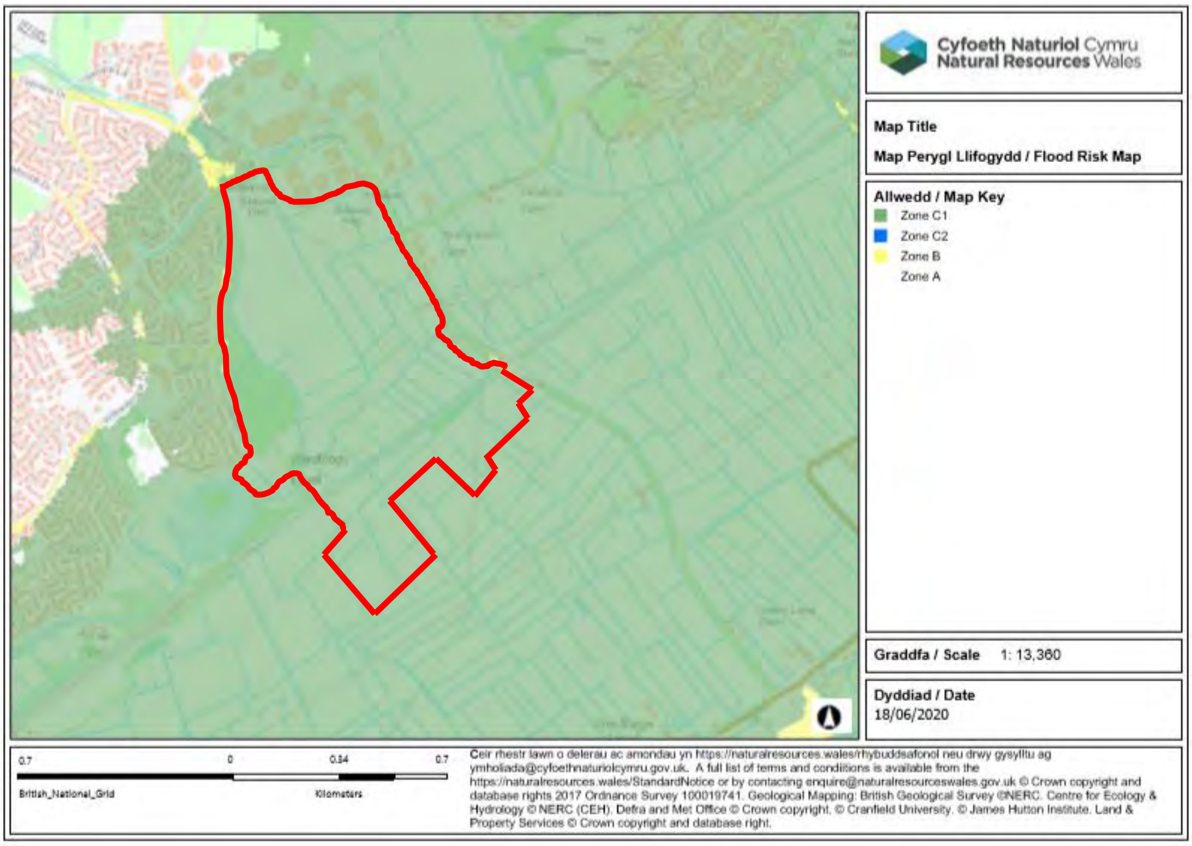

Figure 3-1 Development Advice Map

3.3 Cardiff Council Local Development Plan

The Cardiff Council Local Development Plan[7] provides a framework to show areas where new homes or employment opportunities can be developed and managed within Cardiff and the surrounding area. The plan highlights the need to provide 40,000 new jobs and improved infrastructure across eight strategic development sites within and surrounding Cardiff. The St Mellons site is listed in the LDP as "South of St Mellons Business Park – KP2 (H)" and it is designated as a strategic site for employment.

The plan highlights that flood mitigation works will include raising the development plateaus and providing flood compensation areas south of the railway line. It also highlights that the design should protect the value of the Gwent Levels SSSI, which has been discussed in more detail in Section 4.

The proposed development will help to meet the following Key Polices in The Cardiff LDP. KP6 highlights the need for new infrastructure especially relating to public transport and KP8 highlights the need for that transport to be sustainable. The development will meet this requirement by the construction of Cardiff Parkway station and bus links into the city. This will help to improve the efficiency of the public transport system as well as encouraging sustainable forms of transport.

The development will also help to meet KP9 which involves responding to economic needs. The new development will provide a variety of jobs in different employment areas to help the growth of the Cardiff economy. The development is accessible to known areas of deprivation providing a variety of job opportunities at different skill levels and will help Cardiff meet its target of providing 40,000 new jobs.

[7] Cardiff Local Development Plan 2006-2026 (2016) LINK

3.4 Cardiff Strategic Flood Consequence Assessment

A high-level study of the area was undertaken as part of the Cardiff Strategic Flood Consequence Assessment[8] (SFCA) to assess the risk of flooding from the Wentlooge reen system. The assessment concluded that the most significant source of flooding to the area was from tidal inundation from over topping or a breach of the existing tidal defences. The site, without any mitigation measures, is predicted to be flood free in the 0.5% AEP event. 10% of the site is predicted to be flooded in the 0.1% AEP event, with water levels remaining below 0.6 metres. With the application of climate change (2085) to the 0.5% AEP event, two thirds of the site is predicted to flood.

The assessment identified that raising the development site, creating flood compensation areas and improving culverts could be an effective way to reduce the flood risk on site. The report indicated that there could be localised increases in velocities around the site as a result of the reduced depth of the flood water, but the overall risk was considered reduced relative to the baseline.

3.5 Newport Local Development Plan

The Newport Local Development Plan[9] shows that the site is bounded by the Newport City Council limits. The site is not referred to in the Newport Local Development Plan but given its proximity and the need for works along the boundary, it has been reviewed for this FCA.

SP3 policy relates to flood risk and the need to consider fluvial, tidal, surface water and groundwater flood risk. This is covered in sections 2 and 4 of this FCA report. The LDP is supported by an SFCA but given the site is only bounded by the Newport LDP zone, there was no specific flood risk information relevant to the site.

3.6 Justification Test

TAN-15 states that development will be justified if it can be demonstrated that:

1. *Its location in zone C is necessary to assist, or be part of, a local authority regeneration initiative or a local authority strategy required to sustain an existing settlement;*

or

2. *Its location in zone C is necessary to contribute to key employment objectives supported by the local authority, and other key partners, to sustain an existing settlement or region;*

and

3. *It concurs with the aims of Planning Policy Wales and meets the definition of previously developed land;*

and,

4. *The potential consequences of a flooding event for the particular type of development have been considered and found to be acceptable.*

The proposed development has been assessed against the requirements of the Justification Test with the results summarised in Table 3-2.

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[8] Cardiff Strategic Flood Consequences Assessment Phase 2 Part 1 Update Extend Development Lifetime to 2110 Cardiff Council. Atkins, 2011. LINK

9 Newport Local Development Plan 2011-26 (2015) LINK

Table 3-2 Justification Test applied to the proposed development

TAN 15 Justification Criteria	Comments	Achieved
Its location is necessary to assist a local authority regeneration initiative or strategy, or contribute to key employment objectives, necessary to sustain an existing settlement or region	The proposed development site will assist with KP6,8 and 9 of the Local Development Plan and is listed as a strategic site under Policy KP2 of the LDP	✓
The site meets the definition of previously developed land (i.e. it is not a Greenfield site) and concurs with the aims of Planning Policy Wales (i.e. the presumption in favour of sustainable development)	Whilst the site is Greenfield, it is adjacent to existing residential development and is named within the LDP as a strategic site. It is therefore deemed acceptable for proposed development.	✓
A Flood Consequence Assessment has been produced to demonstrate that the potential consequences of a flood event up to the extreme flood event (1 in 1000 chance of occurring in any year) have been considered and meet the [Acceptability Criteria] … in order to be considered acceptable.	The flood consequences have been assessed and have been found to be acceptable as shown in Section 7.	✓

4 Flood Risk Management Measures

4.1 Integration of Flood Mitigation in Design

The Cardiff SFRA recommended a range of flood mitigation measures for the development of the site. Using detailed flood modelling and iterative and integrated design process these options have been assessed, refined and incorporated into the site parameters plan. The resulting flood mitigation measures provide a high standard of protection whilst being sympathetic to the management and enhancement of the water environment. The flood mitigation measures are all identified on Figure 4-1, and discussed in the following section.

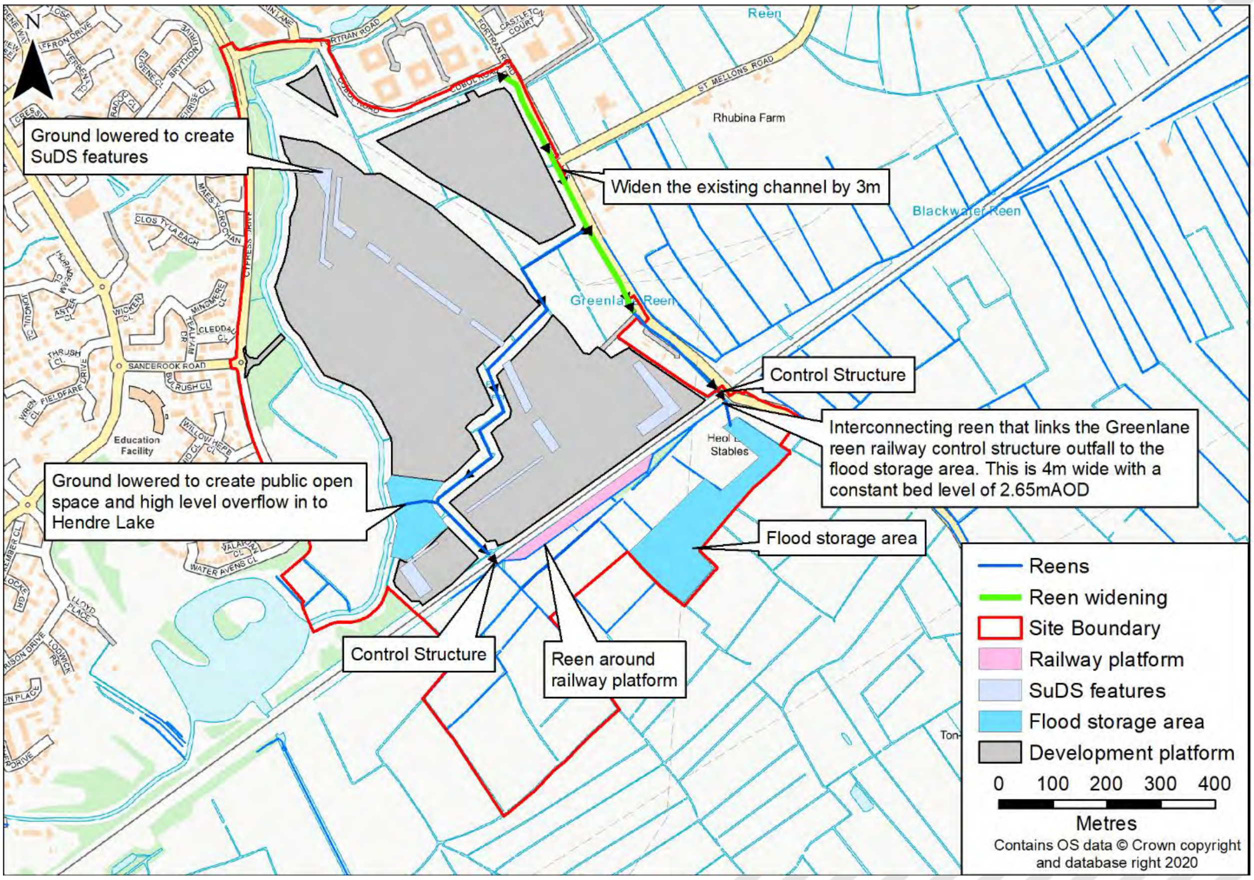

Figure 4-1: Integration of flood mitigation in the design

The primary flood risk management measure is to raise all areas of built development (ie. buildings, roads and parking) to a minimum level of 6.0mAOD. Raising the site to this minimum level will significantly reduce the risk of flooding from all sources, including tidal, fluvial, surface water and groundwater. Furthermore, the site parameters plan has been developed to maintain the main reens and provide green/blue corridors. A level of 7.0mAOD has been assumed for the railway station platform as it will need to be elevated above the railway line.

The proposed ground raising will lead to some loss of floodplain storage. Tidal flooding is generally insensitive to the loss of floodplain storage, as the volume of the sea is essentially infinite in comparison to the floodplain. However, in some circumstances, such as when coastal defences overtop, the volume of available floodplain can play a role in the flood risk. Consequently, so that there are no negative flood risk effects, several areas of the site have been deliberately lowered to offset the ground raising effects and provide ecological mitigation. The largest of these areas is immediately south of the railway line, with another smaller area in the southwest corner of the site.

The complex reen network is able drain floodwater in a myriad of directions under a range of different conditions (tidal and fluvial). Through detailed hydraulic modelling of the area it was found that maintaining and balancing the conveyance of floodwater through and across the site was key to avoiding negative effects. Consequently, the Greenlane reen will be widened by 3 metres from the Cobol Road/ Fortran Road junction southwards to a point close to the gas reduction station on Heol Las road. This will improve the conveyance of flood water around the edge of the proposed development.

The Ty-Fynnon Reen which runs through the middle of the development site will not be widened. For the post development modelling scenario, a consistent bed level was used to help smooth out some LIDAR discrepancies in this reen.

To the south of the railway line, a new reen will be constructed that links the Greenlane reen railway structure to the flood storage area. This has been schematised within the hydraulic model as a 4m wide reen with a constant bed level of 2.65mAOD within the model.

Hydraulic control structures are also proposed on the two culverts under the railway line to prevent tidal flood water from entering the site via the Greenlane or Ty-Fynnon reens.

5 Assessment of Tidal Flood Risk

5.1 The Wentlooge Model

In 2014, JBA Consulting were commissioned by Natural Resources Wales (NRW) to carry out a study of the Caldicot and Wentlooge Levels[10] in South East Wales. The overall aim of the project was to improve NRW's understanding of the coastal flood risk in the study area spanning from Cardiff to Chepstow. The project looked in detail at wave conditions, wave overtopping, defended, undefended and asset failure scenarios. This project was completed in 2016 and now provides a comprehensive understanding of flood risk for this study area.

The NRW study modelled the Caldicot and Wentlooge Levels as discreet models. Therefore, for this study the Wentlooge model was used. The extent and arrangement of the Wentlooge model is shown in Figure 5-1.

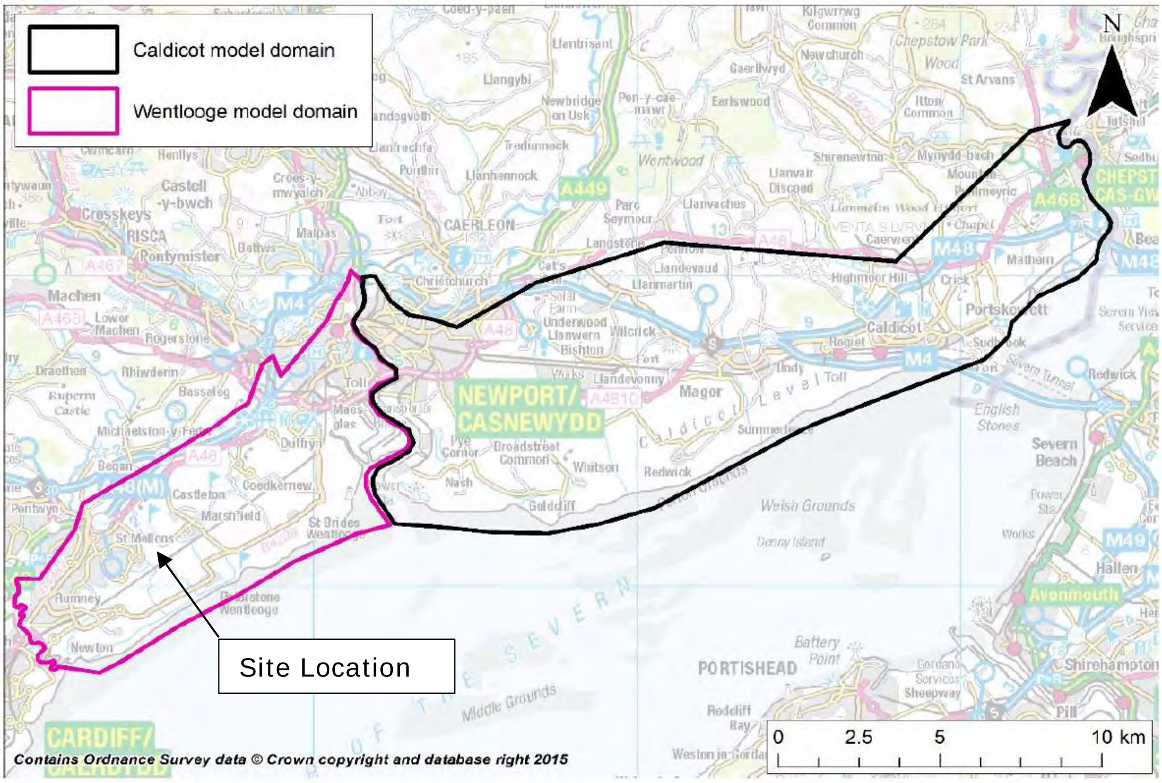

Figure 5-1 Extent of the Wentlooge model[10]

5.2 FCA Flood Modelling

To inform the FCA, the results of five key simulations were assessed:

- Pre-development
  - 0.5% AEP plus climate change
  - 0.1% AEP plus climate change
- Post-development
  - 0.5% AEP plus climate change
  - 0.1% AEP plus climate change

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[10] JBA Consulting. Caldicot and Wentlooge Coastal Modelling Summary Report. June 2016

- o Flood defence breach: 0.1% AEP plus climate change

All of design events incorporate the influence of climate change for the 75yr lifetime of the development (up to the year 2095).

New extreme sea level predictions for the UK were released in 2019[11], at a time when much the hydraulic modelling work had already been completed. The new extreme sea level estimates show that there is a 0.13m to 0.30m decrease in the predicted extreme sea level values compared to the 2008 data used in the 2014 Wentlooge Model. Table 5-1 shows a comparison of the modelled tide level and new tide levels across the model's coastal boundary.

As the new Extreme Sea Level Estimates were published during this study and the water levels were lower for the new estimates, it was decided that these estimates would not be updated in the model. Consequently, extreme sea levels remain based on the previous 2008 estimates and provide a precautionary assessment of tidal flood risk.

Table 5-1 Comparison of new and model sea level nodes

		Modelled Tide Levels		New Tide Levels	
	Sea level node	CC 2092		CC 2095	
		T200	T1000	T200	T1000
Usk River	Tide_396	9.21	9.54	9.07	9.41
	Tide_397	9.18	9.50	NA	NA
	Tide_398	9.14	9.46	8.99	9.33
	Tide_400	9.10	9.45	8.92	9.26
	Tide_401	9.08	9.43	NA	NA
	Tide_402	9.07	9.42	8.85	8.78
	Tide_404	9.03	9.40	8.78	9.13
	Tide_405	9.01	9.39	NA	NA
	Tide_406	NA	NA	8.71	9.07
Rhymney River	Tide_408	8.95	9.35	8.65	9.01

5.3 Tidal Flood Risk – Pre Development

Under present day conditions (2020) the site is predicted to be entirely free of tidal flooding in the 0.1% AEP event. Consequently, tidal flood risk has only been considered within this assessment with the influence of climate change to the year 2095.

0.5% AEP Event plus climate change (2095)

During a 0.5% AEP tidal event with the application of climate change, the proposed development site is predicted to be flood free. Large areas of agricultural land to the south of the railway line are predicted to flood, but flood water does not reach the site, as shown in Figure 5-2. Localised flooding of reens occurs to the south and east of the site.

11 Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018). Environment Agency.

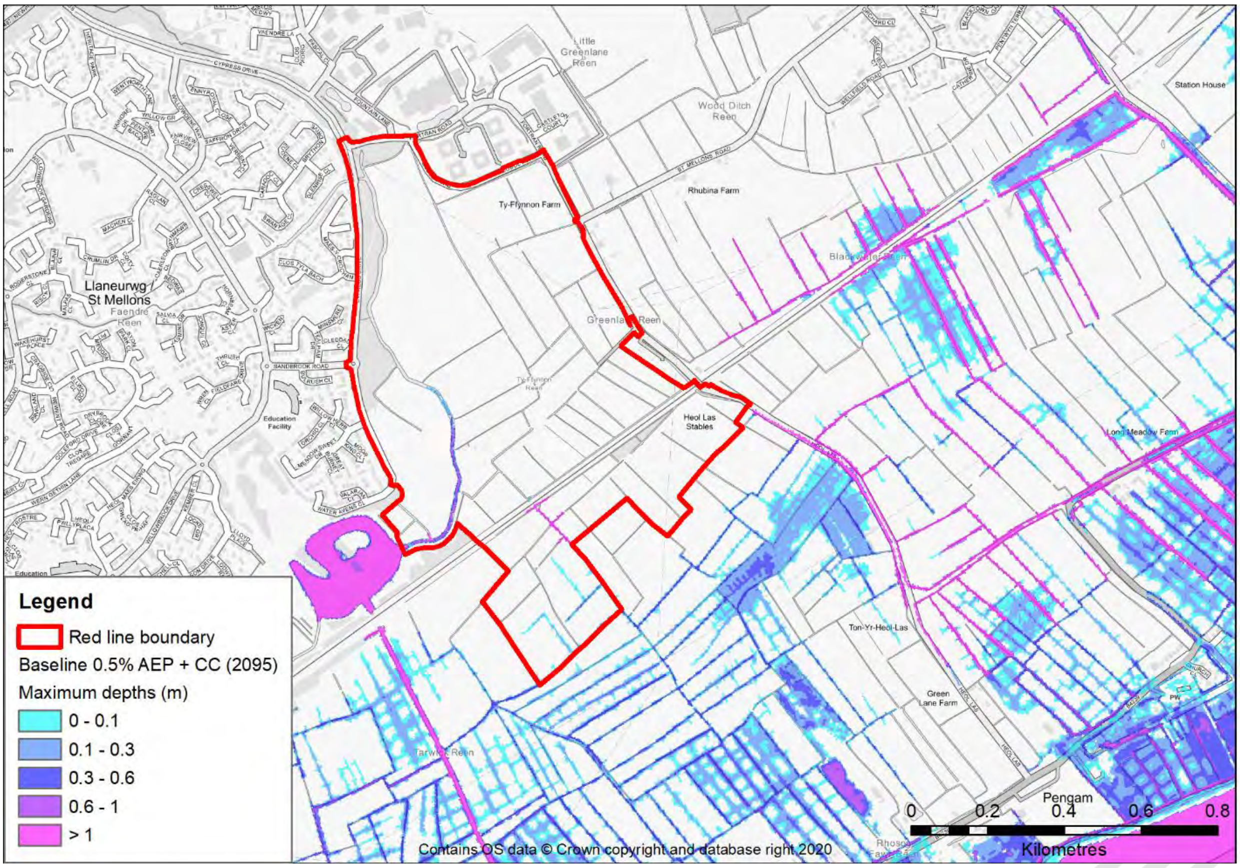

Figure 5-2 0.5% AEP event plus climate change - Baseline event

0.1% AEP Event plus climate change (2095)

During the 0.1% AEP event with the application of climate change, the proposed development site is predicted to flood in the south and north eastern areas of the site, as shown in Figure 5-3.

In the northern area of the site flood depths do not generally exceed 0.1m; with only localised areas around the reens predicted to flood to a maximum flood depth of 0.3m.

In the southern area of the site, deeper flooding occurs in the south western corner, due to the lower topography of the area. Flood water surrounding the reens reaches a maximum depth of 0.5m, with most depths not exceeding 0.4m.

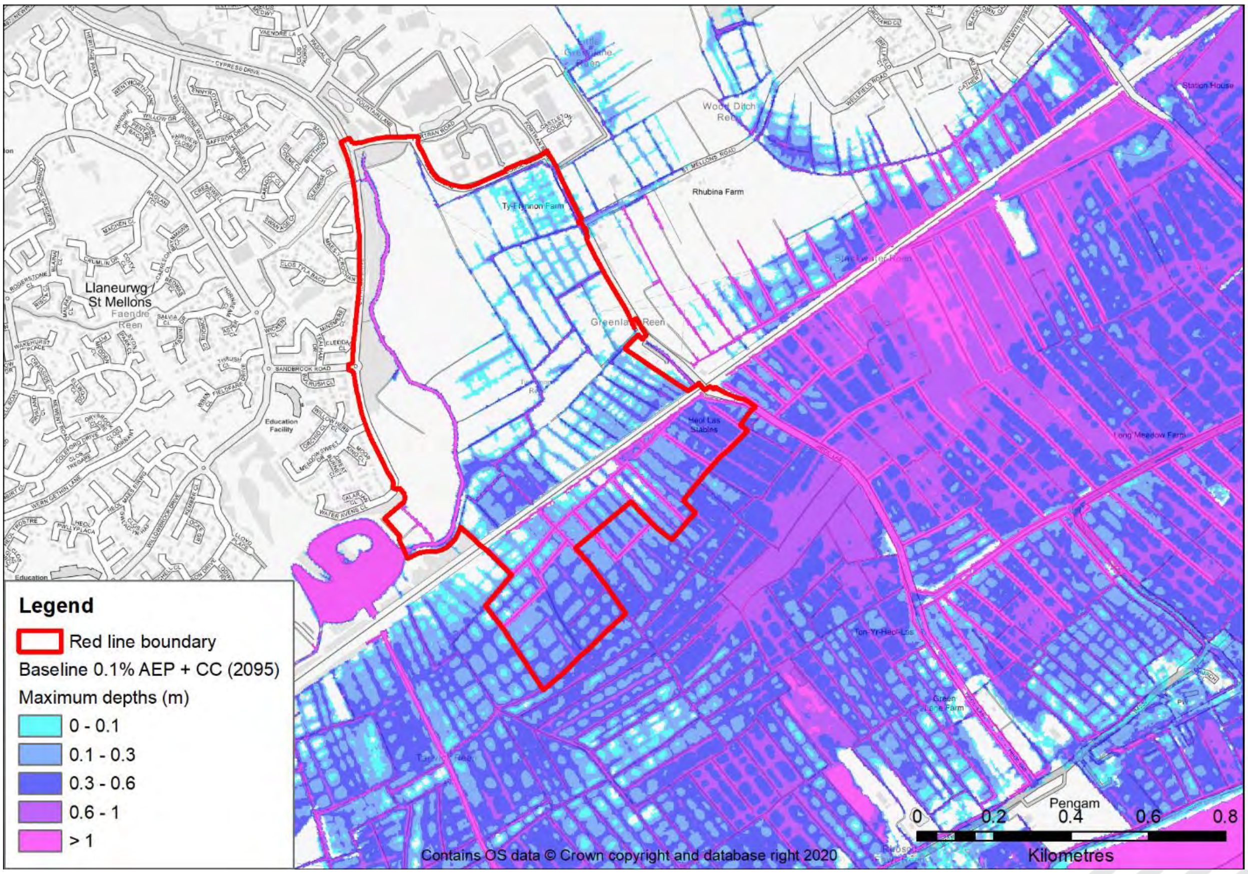

Figure 5-3 0.1% AEP event plus climate change - Baseline event

5.4 Tidal Flood Risk – Post Development

The mitigation strategy, outlined in Section 4, involves raising ground levels to a minimum of 6.0mAOD to create a development plateau on the site. In addition, the culverts running below the railway embankment have been updated to prevent tidal inundation to the north of the railway embankment, and the network of reens on site were altered.

0.5% AEP Event plus climate change (2095)

During a 0.5% AEP tidal event with the application of climate change, the proposed development site is predicted to be flood free. Large areas of agricultural land to the south of the railway line floods, but flood water does not reach the site, as shown in Figure 5-4. Localised flooding of reens occurs to the south and east of the site.

There is little difference between the pre and post development flood water depths for the 0.5% AEP event plus climate change.

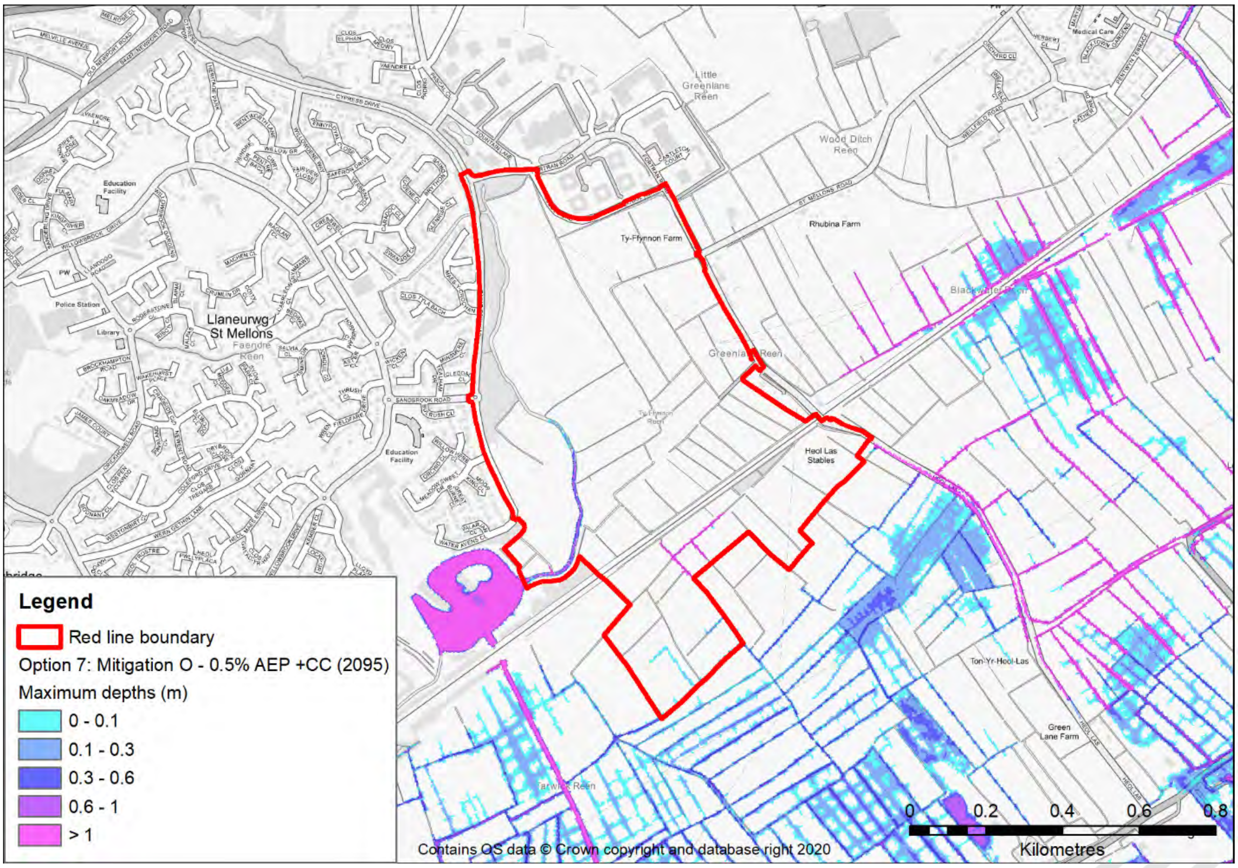

Figure 5-4 0.5% AEP event plus climate change (2095)

0.1% AEP Event plus climate change (2095)

During the 0.1% AEP event with the application of climate change the proposed development site is predicted to be flood free apart from an area of public open space in the southwest corner, as shown in Figure 5-5. All areas of built development are predicted to remain flood free in this extreme event.

In the pocket of flooding in the southwest corner of the site flood water reaches an average depth of 0.14m with some localised depths of up to 0.48m. This area has deliberately designed to flood in this event to maintain connectivity between the Faendre and Ty-Ffynnon reens. At all other times this area will provide valuable public open space.

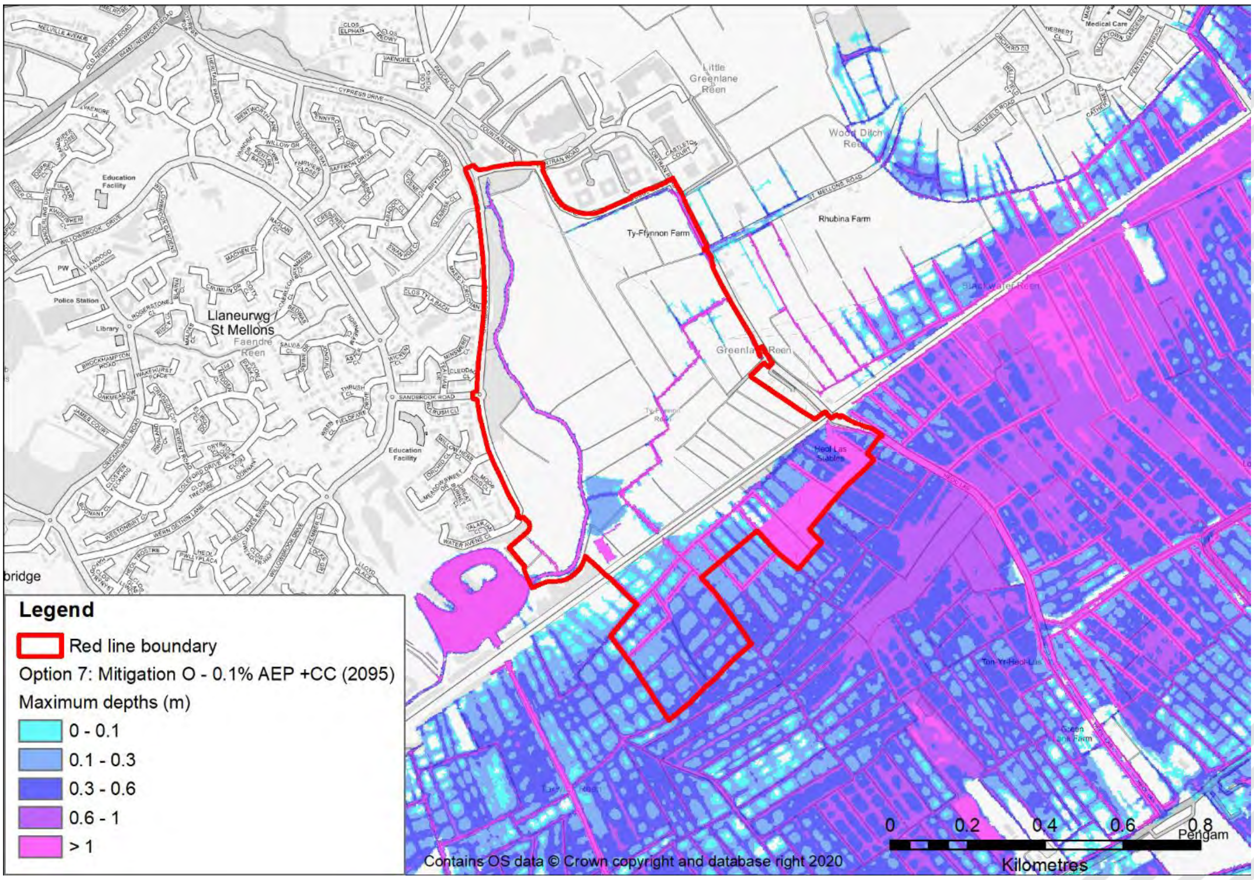

Figure 5-5 0.1% AEP event plus climate change (2095)

Residual flood risk: 0.1% AEP Event plus Climate Change (2095) with Breach

This scenario has been considered to assess residual flood risk to the site from a breach of the tidal defences that protect the Wentlooge levels. Irrespective of the likelihood of this event the primary objective of assessing the residual flood risk is to safeguard the risk to life.

The residual risk scenario couples the 0.1% AEP plus climate change event with simultaneous breaches in the coastal flood defences at seven different locations. Details of all seven breaches are described in Table 5-2 and shown in Figure 5-6. Within the NRW Caldicot and Wentlooge modelling study, this breach scenario is identified as Breach Scenario B6. This scenario was chosen as it was the worst-case scenario from the study.

Table 5-2 Dimensions of breaches in tidal defences in the Wentlooge tidal flood model

Defence	Return Period	Peak Breach Outflow (m^3/s)	Final Breach Depth (m)	Final Breach Width (m)
3	0.1% AEP + CC	41.37	2.46	7.66
4	0.1% AEP + CC	32.83	2.79	6.70
5	0.1% AEP + CC	99.88	4.06	10.96
8a	0.1% AEP + CC	668.00	2.56	89.78
8b	0.1% AEP + CC	524.11	2.56	70.79
8c	0.1% AEP + CC	1392.25	2.56	179.90
9	0.1% AEP + CC	358.04	2.09	68.99

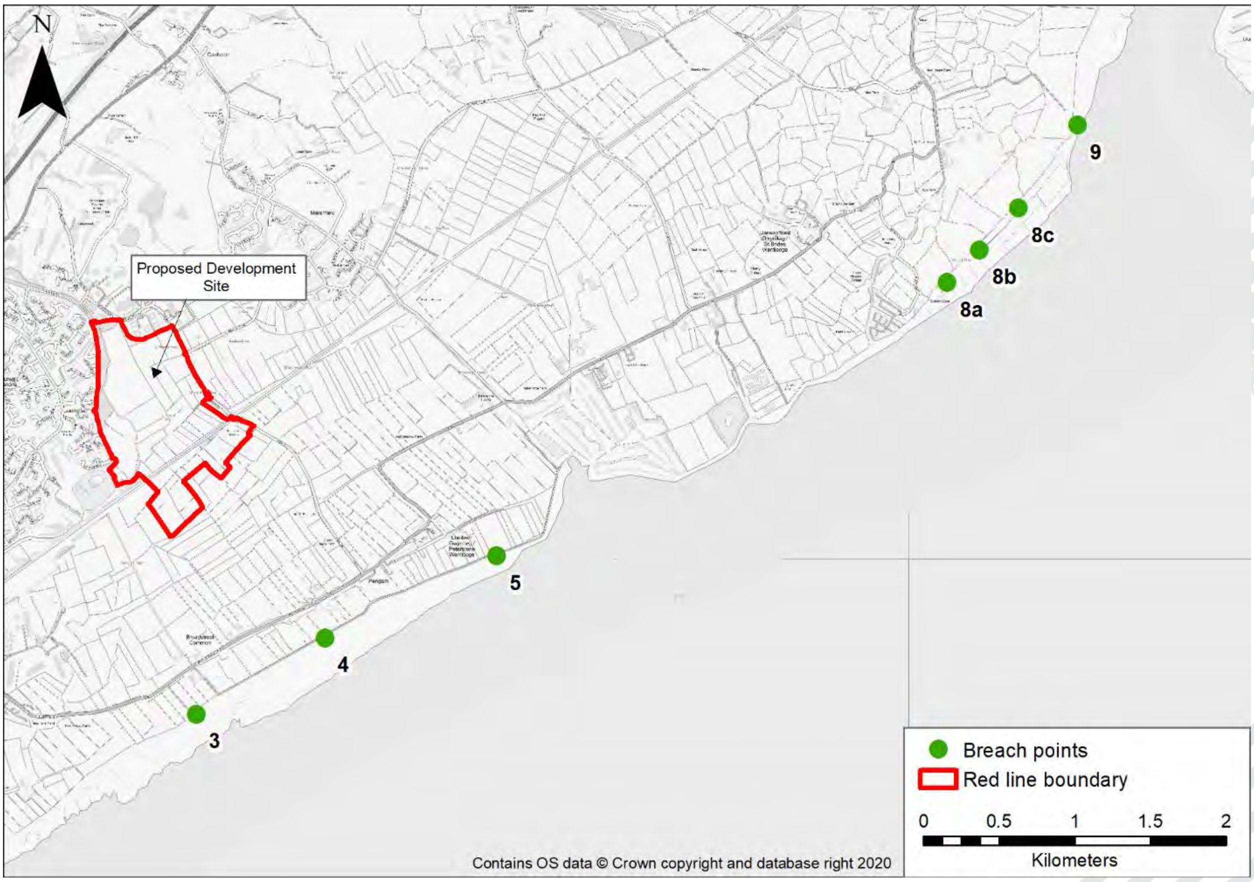

Figure 5-6 0.1% AEP plus climate change - Breach Locations

During the breach scenario, the proposed development site is predicted to flood, as shown in Figure 5-7. Where the ground level has been raised to 6.0mAOD to create the development platform, the maximum flood depths in these areas are 0.31m. In areas of public open space and in the reens flood depths exceed 1m.

Safe access/egress routes to the site are shown in Figure 5-7 with a flood depth less than 0.6m on all routes. A summary of flood levels across the site for the extreme events is provided in Table 5-3 below.

It is noteworthy that the NRW breach results are based on the simultaneous breach failure of seven locations along the coast. These results can therefore be assumed to be extremely precautionary, representing a highly unlikely worst-case scenario.

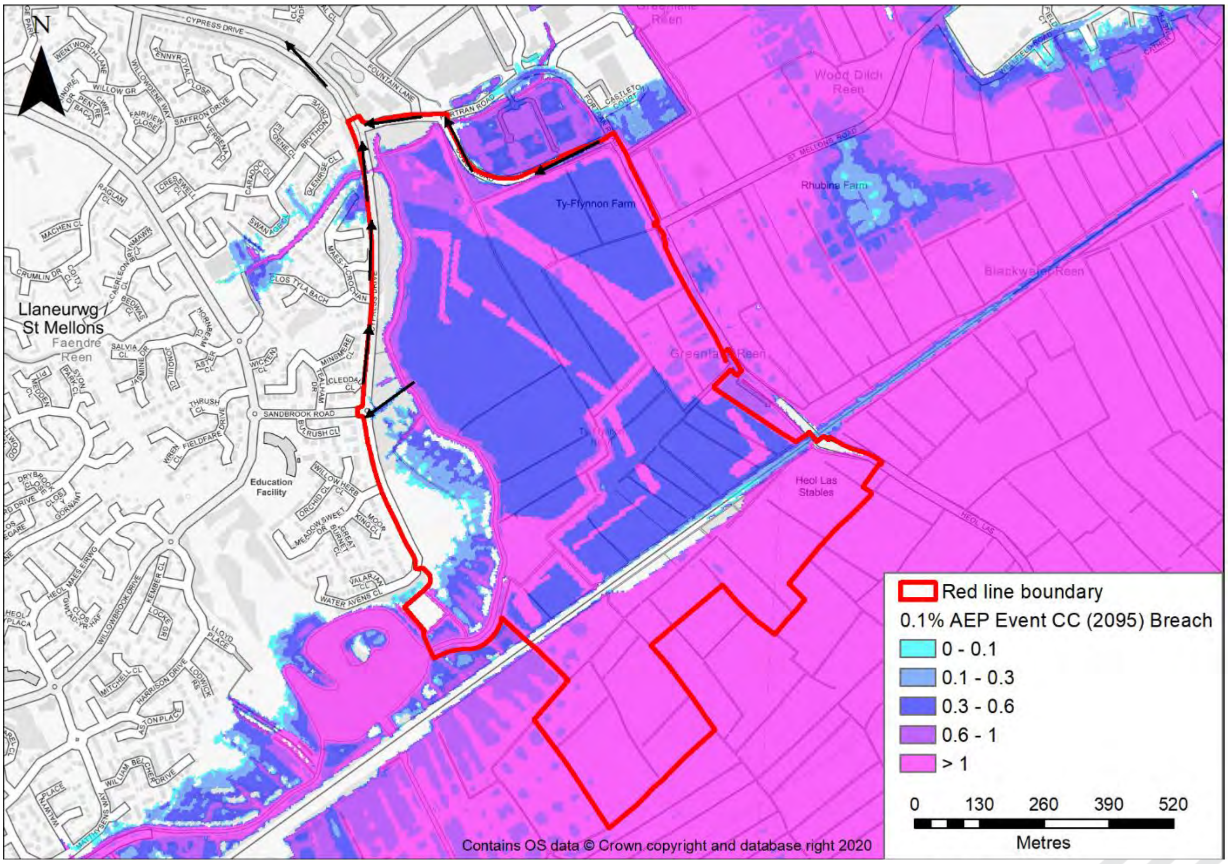

Figure 5-7 0.1% AEP event plus climate change (2095) - Breach Scenario

Table 5-3 Summary of site and flood levels

	Event	Maximum Flood Level(mAOD)	Ground Level (mAOD)
Post-development	0.1% AEP plus climate change	5.05	6.00
	0.1% AEP plus climate change - Breach	6.31	6.00

6 Assessment of Pluvial Flood Risk

6.1 The Pluvial Model

The complex arrangement of watercourses that intersect and surround the site are generally highly effective in draining the area, although some degree of fluvial risk may persist. The Cardiff Strategic Flood Consequence Assessment undertook high level fluvial flood risk modelling of the site in 2012 and predicted widespread flooding of the site (Section 2.7).

JBA licensed the SFCA fluvial flood model from NRW and undertook a comprehensive review of the model. This identified a number of highly conservative assumptions and simplifications had been made in the modelling:

1. Initial water levels were set in the model base on the 0.1% AEP Flood Map for Surface Water. Therefore, all watercourses were already in extreme flood at the start of the simulation, before further flows were then added.
2. The tidal outfalls were not included in the flood model. Therefore, the Wentlooge levels had no way to discharge to the sea.
3. A standardised point inflow approach was used to apply flows to the hydraulic model. This simplified method is not best suited for modelling a catchment that encompasses a series of small interconnecting reens.
4. The reens and key hydraulic structures were modelled using limited data and simplified approaches.

In consultation with NRW, JBA undertook a comprehensive modelling exercise to address the SFCA limitations. The model took the best information from both the NRW Wentlooge and Cardiff SFCA models, and combined this with new data, new hydrology and the latest modelling methods. The resulting model is a 1D-2D ESTRY-TUFLOW model of a large area around the site. It includes a detailed representation of all key structures, reens and tidal outfalls. The initial water level applied to the model is more in keeping with typical conditions.

The JBA assesses both fluvial and surface water flood risk together with a hybrid approach to the hydrology, see Appendix C. This approach applies point inflows to upstream model boundaries together with direct rainfall to the 2D domain in the area of interest. The model is thereby able to best capture the complex hydrological and hydraulic response of the catchment. We have therefore referred to the modelling as a 'pluvial' model; capturing both fluvial and surface water flood risks. As the model is in the River Severn basin district, 25% climate change has been applied to the fluvial and pluvial elements of the model in line with central estimate for climate change in this area[12]. Further information on the model can be found in Appendix D.

As is typical with all direct rainfall models and in keeping with the approaches used with the Flood Map for Surface Water[13], a minimum flood threshold of 0.15m has been applied to flood risk mapping. Below this threshold the flood risk is considered to be negligible.

6.2 Pluvial Flood Risk – Pre-Development

1% AEP Event plus Climate Change (25%)

During the 1% AEP event with the application of climate change, there is no significant out of bank flooding predicted at the development site, as shown in Figure 6-1. In localised areas, such as the south west of the site, the maximum flood depth is predicted to be 0.22m. This flooding is generally associated with field drainage depressions, that intentionally collect rainfall. There is not out-of-bank flooding of a fluvial nature.

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[12] Welsh Government (2017) Adapting to Climate Change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales. LINK

[13] The Environment Agency (2019) What is the Risk of Flooding from Surface Water map? LINK

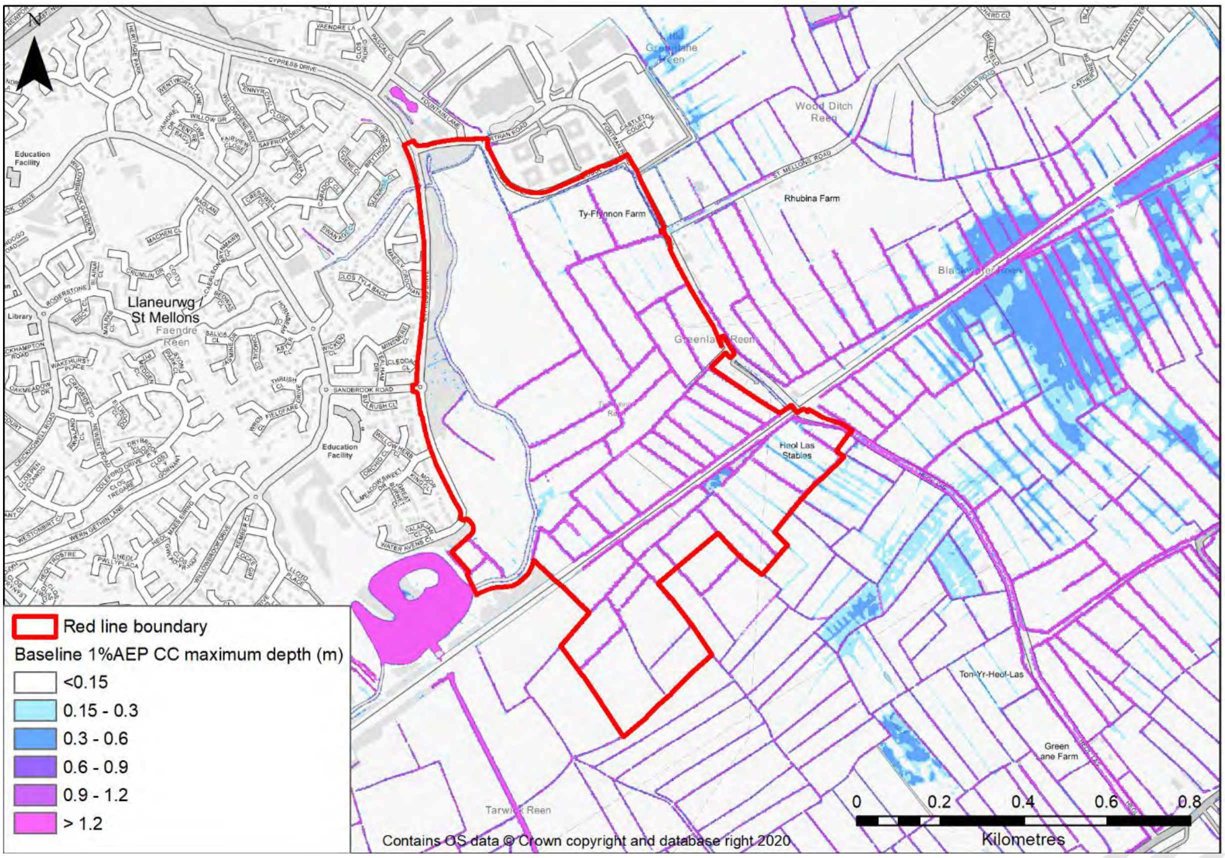


Figure 6-1 1% AEP event plus climate change - Baseline event

0.1% AEP Event

During the 0.1% AEP event no significant out of bank flooding is predicted within the development site, as shown in Figure 6-2. In keeping with the 1% AEP plus 25% climate change results, some localised surface water flooding is reported of local depressions to a maximum depth of 0.35m. There is not out-of-bank flooding of a fluvial nature.

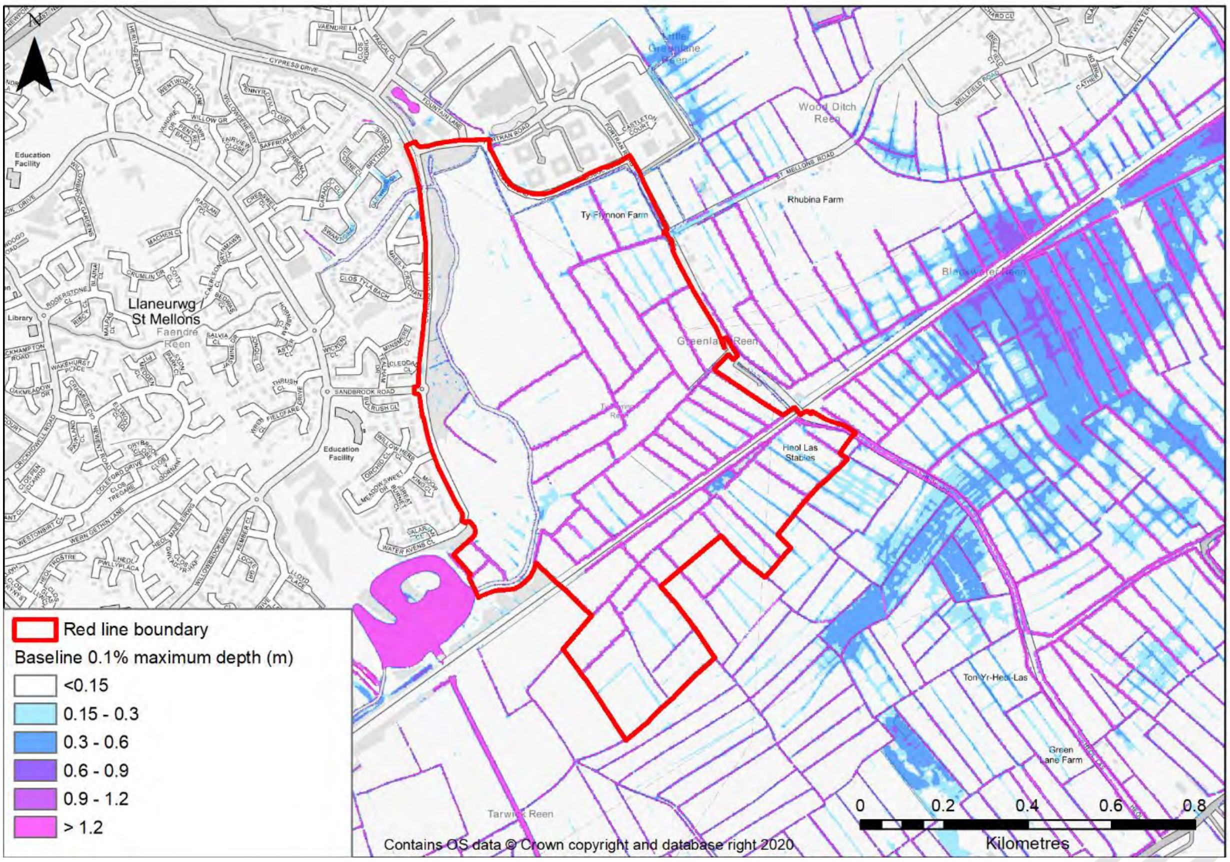


Figure 6-2 0.1% AEP event - Baseline event

6.3 Pluvial Flood Risk – Post Development

In keeping with the previous tidal flood risk modelling (Section 5), the proposed development and flood mitigation measures were applied to the pluvial flood model. The results are presented below.

1% AEP Event plus Climate Change (25%)

During the 1% AEP event with the application of climate change all areas of built development site are predicted to be flood free, as shown in Figure 6-3. Localised flooding is only reported in areas intended as blue/green corridors or public open space.

Consequently, in the 1% AEP plus climate change event, there is little or no risk of fluvial and surface water flooding within the site.

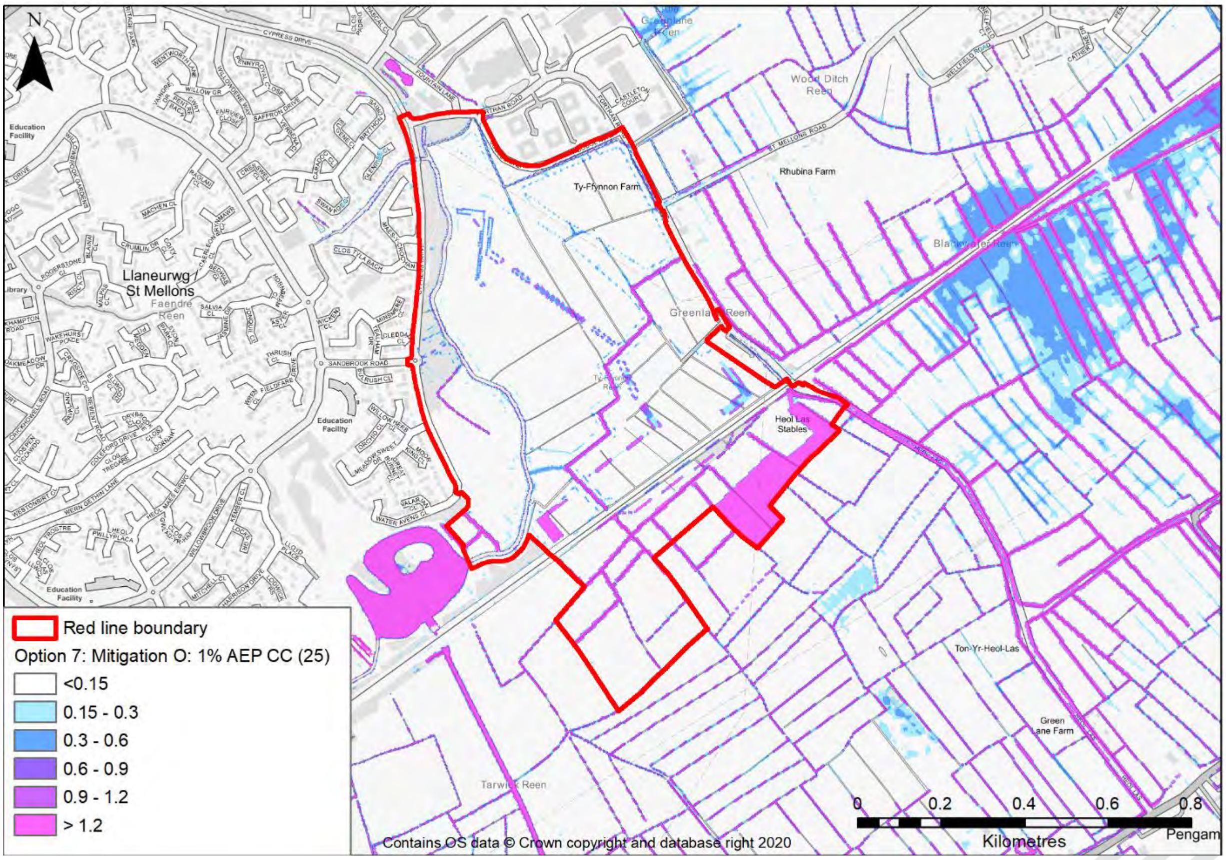


Figure 6-3 1% AEP event plus climate change with mitigation

0.1% AEP Event

During the 0.1% AEP event with the application of climate change all areas of the built development site are predicted to be flood free, as shown in Figure 6-4. Localised flooding is only reported in areas intended as blue/green corridors or public open space.

Consequently, in the 0.1% AEP event, there is little or no risk of fluvial and surface water flooding within the site.

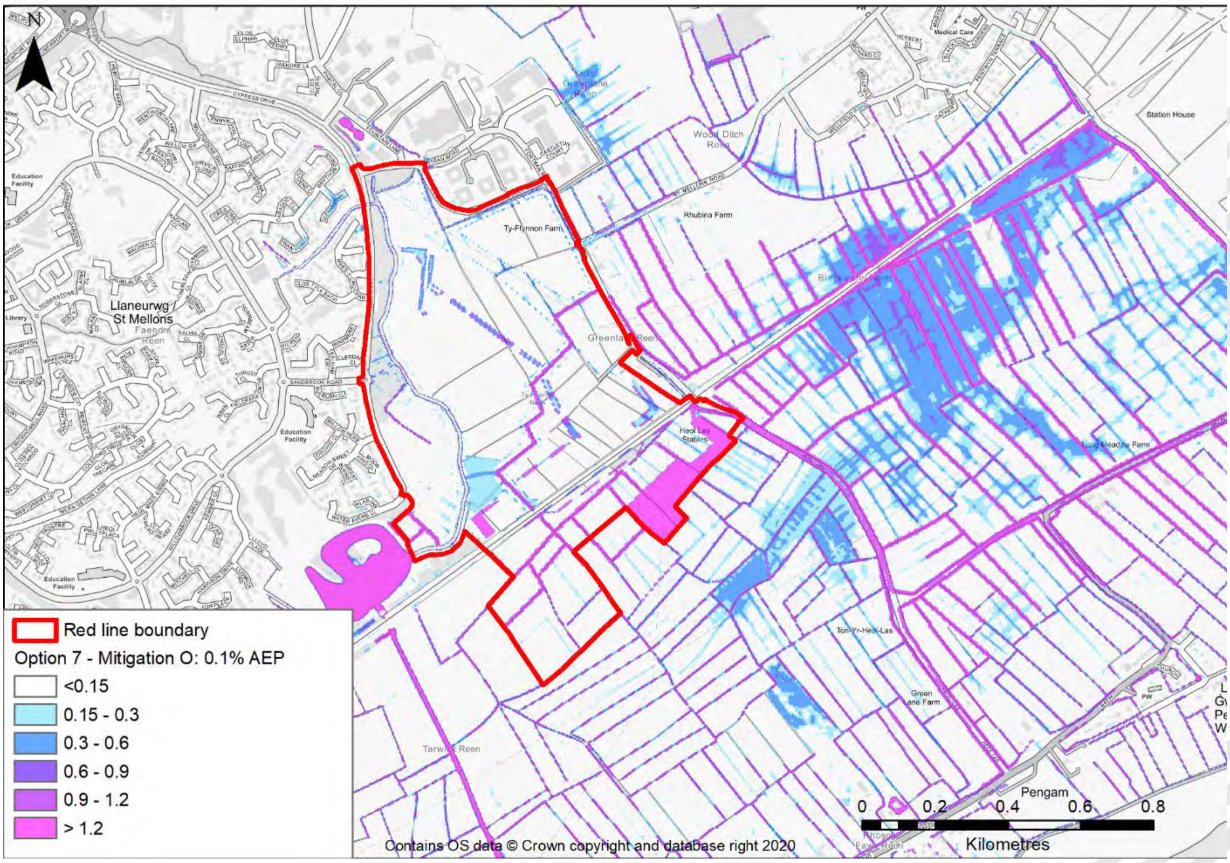


Figure 6-4 0.1% AEP event with mitigation

7 Assessment of Acceptability Criteria

TAN-15 states that for less vulnerable development to be considered within Zone C1, the proposed development must meet the requirements set out within the Justification Test including the Acceptability Criteria. An assessment of the Acceptability Criteria is detailed in the following section. These criteria should be satisfied in order for the proposed development to comply with TAN-15.

7.1 Acceptability Criteria 1 [A1.12]

Flood defences must be shown by the developer to be structurally adequate particularly under extreme overtopping conditions (i.e. a flood with a probability of occurrence of 0.1%).

The Caldicot and Wentlooge flood defences are amongst the most important flood defences in Wales; protecting many properties and key infrastructure. During the M4 relief road enquiry Welsh Government gave strong reassurances that these flood defences would be maintained and improved in line with climate change predictions. Therefore, there can be a high degree of confidence in the long-term maintenance and upkeep of the defences and the maintenance of the standard of protection in line with the Shoreline Management Plan (SMP) recommendations.

Whilst the breach scenario demonstrates the residual flood risk to the site it remains well below the acceptability criteria (ie. flood depths <600mm) set out in A1.15 of TAN15.

The scheme satisfies the requirements of this acceptability criteria.

7.2 Acceptability Criteria 2 [A1.12]

The cost of future maintenance for all new/approved flood mitigation measures, including defences must be accepted by the developer and agreed with NRW.

The developable areas of the proposed site will be raised to a minimum ground level 6.00mAOD. A flood compensation area will be created to the south of the site to compensate for the proposed ground raising. Both of these flood mitigation measures are essentially passive once constructed, requiring little or no maintenance.

Furthermore, two hydraulic control structures are proposed on the two culverts under the railway line. These form part of the water level management infrastructure on the levels and will therefore be adopted and maintained by the Internal Drainage Board.

The scheme satisfies the requirements of this acceptability criteria.

7.3 Acceptability Criteria 3 [A1.12]

The developer must ensure that future occupiers of development are aware of the flooding risks and consequences.

The occupants and business owners of the proposed development should sign up to NRW's Flood Warnings service[14] to provide a warning in the event of a predicted extreme flood event. A Flood Action Plan should be developed and adopted to ensure correct action is taken in the event of a Flood Warning being issued. Each business should be encouraged to create their own emergency flood plan detailing evacuation routes, important phone numbers and a business continuity plan.

The scheme satisfies the requirements of this acceptability criteria.

7.4 Acceptability Criteria 4 [A1.12]

Effective flood warnings are provided at the site.

The site is included within the "Coast from Aberthaw to Severn Bridge" flood alert area which covers much of the South Wales coastline. The site is also included within the "Coast at Wentlooge Levels in the Cardiff Area" flood warning area. NRW provide a comprehensive flood

[14] Natural Resources Wales. LINK

warning service for this area with a target to warning at least 24 hours in advance. Site occupiers and businesses should be encouraged to sign up for these warnings.

Furthermore, the Wentlooge levels provide an extremely large flood compensation area such that a single failure in the flood defences would take considerable time to fill the Levels and pose a significant risk to the site.

The scheme satisfies the requirements of this acceptability criteria.

7.5 Acceptability Criteria 5 [A1.12]

Escape/evacuation routes are shown by the developer to be operational under all conditions

The proposed development will be served by a primary and secondary access point, together with a number of tertiary vehicle and pedestrian access points. The primary access point is on the north western boundary of the site which joins Cypress Drive. This access point remains flood free in all events.

The secondary access point is on the western boundary of the site which also joins Cypress Drive at the roundabout on Sandbrook Road. This access route has flood depths less than 0.15m with some localised areas of flooding up to 0.3m in the breach event. These deeper areas of flood water still allow safe access and egress to the site.

There are two vehicle access points on the northern boundary of the site that lead on to Cobol Road. Both of these access points and the Cobol Road traveling north, are flood free in all flood events.

In the breach scenario the access/ egress points on site flood to depths less than 0.6m. These flood depths accord with the requirement of section A1.15 of TAN15.

We therefore conclude that the proposed development site has sufficient access and egress provision to allow for the safe movement of site users and emergency services, thus satisfying the requirements of this acceptability criteria.

7.6 Acceptability Criteria 6 [A1.12]

The development is designed by the developer to allow the occupier the facility for rapid movement of goods/possessions to areas away from the floodwaters

The developable area of the site will be raised to minimum level of 6.00mAOD and is predicted not to flood in the 0.1% AEP plus climate change tidal event. Only in the very unlikely scenario of multiple flood defences failures will the site flood, in which case flood depths will not exceed 0.31m. Such shallow flood depth would not affect the rapid movement of people or goods away from floodwaters.

The scheme satisfies the requirements of this acceptability criteria.

7.7 Acceptability Criteria 7 [A1.12]

Development is designed to minimise structural damage during a flooding event and is flood proofed to enable it to be returned to its prime use quickly in the aftermath of the flood

Due to the low level of flood risk at the development site this measure is not applicable to the development.

7.8 Acceptability Criteria 8 [A1.12]

Development at the site must not cause flooding elsewhere

Compliance with this requirement has been assessed for both tidal and pluvial sources of flood risk. Consideration has been given to the potential for off-site impacts by comparing the flood depth model results, pre- and post-development to assess any change in water depth as a consequence of the proposal. In accordance with NRW FCA guidance, any increase greater than 5mm has been reported.

It should be appreciated that the NRW Wentlooge flood model is extremely large, with very large volumes of water coming and going from the model, combined with a very a complex floodplain topography. Consequently, a degree of model instability is inherent and unavoidable in the flood model. Therefore, changes in flood depth may be associated with these instabilities rather than any true hydraulic process. This is particularly the case for the pluvial flood model, as the modelling approach is inherently more unstable with the direct application of rainfall across the 2D domain.

Tidal

In the post development 0.5% plus climate change scenario (2095), the site is flood free. Figure 7-1 shows a comparison of flood depths. This shows that this is no increase in flooding related to the proposed development in this event.

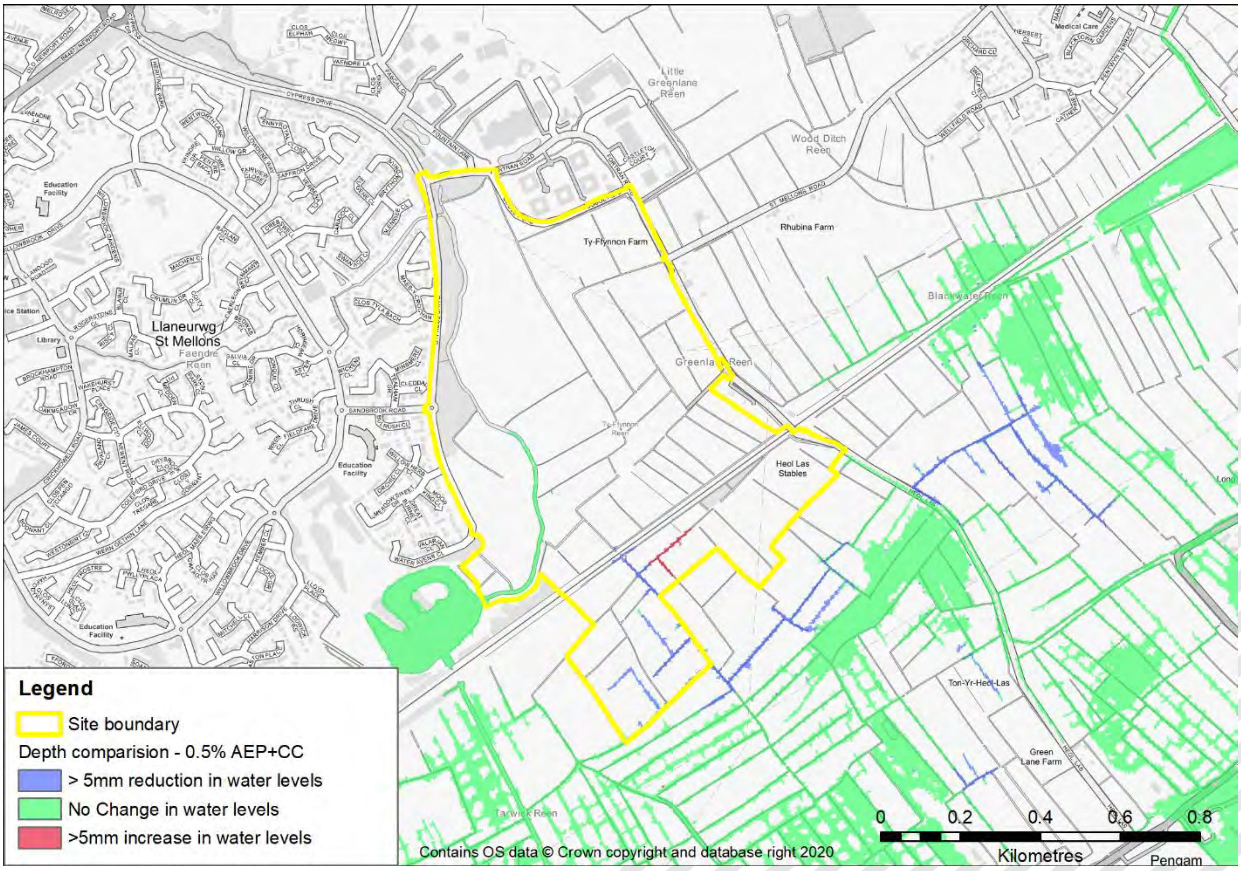


Figure 7-1 Pre and post development depth comparison - 0.5% AEP plus climate change (2095) event

In the post development 0.1% AEP scenario plus climate change scenario (2095) there is greater variation in the flood depths as a result of the proposed development, as shown in Figure 7-2. However, all increases in flood depths are in areas directly associated with the flood risk management of the development. There are no negative effects to third parties.

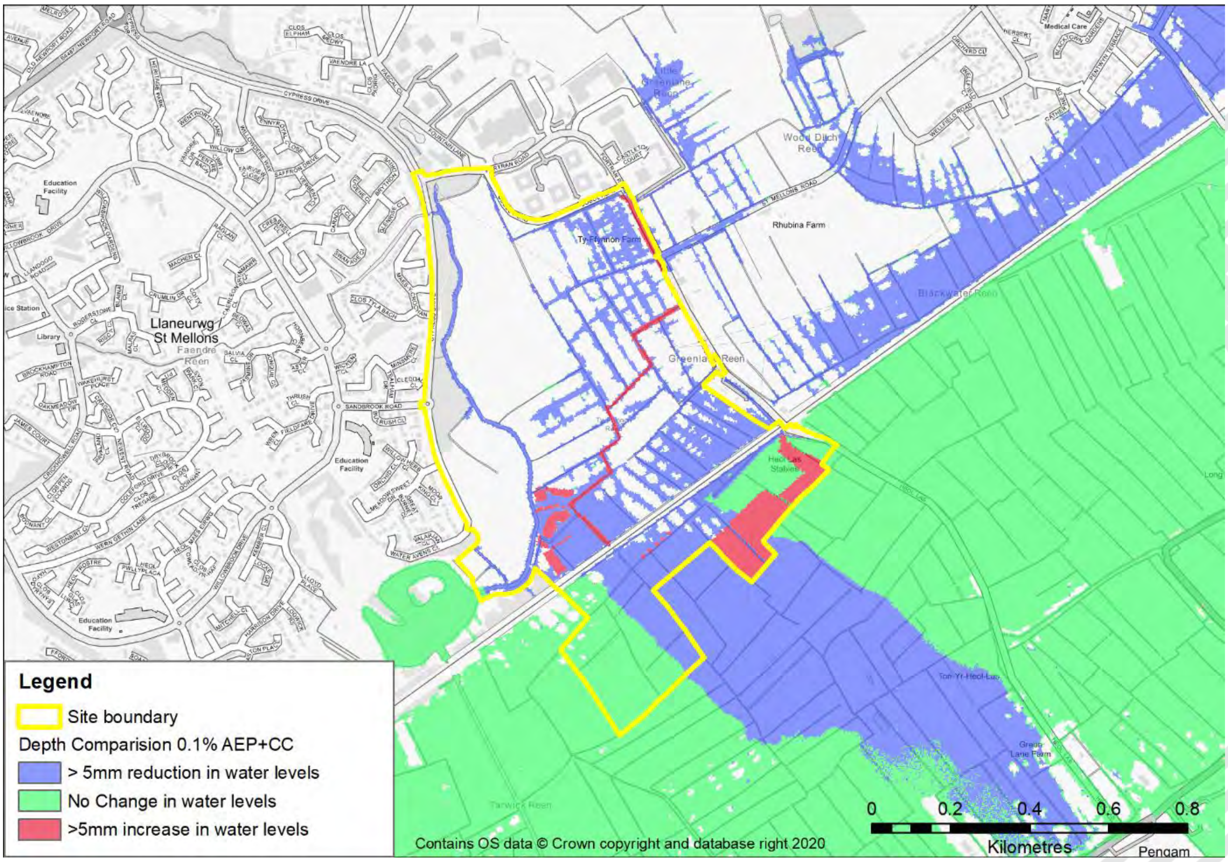


Figure 7-2 Pre and post development depth comparison - 0.1% AEP plus climate change (2095) event

Pluvial

In the post development 1% AEP plus climate change scenario event, the flood depths generally remain the same or decrease by over 5mm in the areas surrounding the site as shown in Figure 7-3. Areas of increased flood depths are generally limited to the development site or the flood compensation area and are therefore intentional.

There are small localised areas of increased flood depths surrounding the site. Flood depths in these areas are associated with very shallow surface water flooding not exceeding 0.05m. Such shallow surface water flooding is well below the 0.15m threshold applied to surface water flood mapping, and therefore by most definitions these areas are not 'flooding'. Furthermore, given the locations and spread of these localised increases it is likely that these are modelling artefacts and not a consequence of the development proposals.

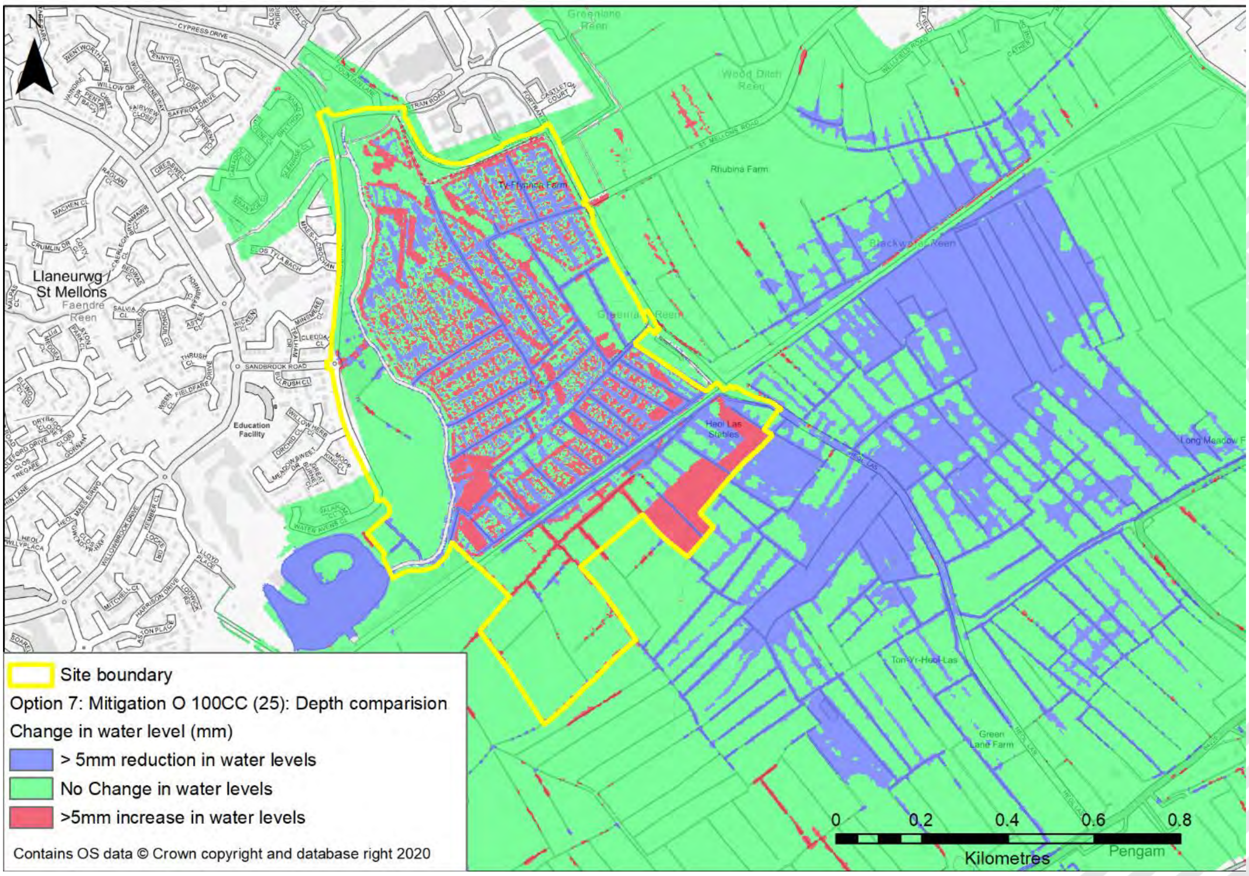


Figure 7-3 Pre and post development depth comparison - 1% AEP (25%) event

In the post development 0.1% AEP scenario, the flood depths remain the same or decrease by over 5mm in almost all areas surrounding the site, as shown in Figure 7-4.

There are several reens that see water level increase just over the 5mm threshold. These increases do not cause out-of-bank flooding and are likely to be associated with model instabilities given the general trend of reducing flood depths in the surrounding areas.

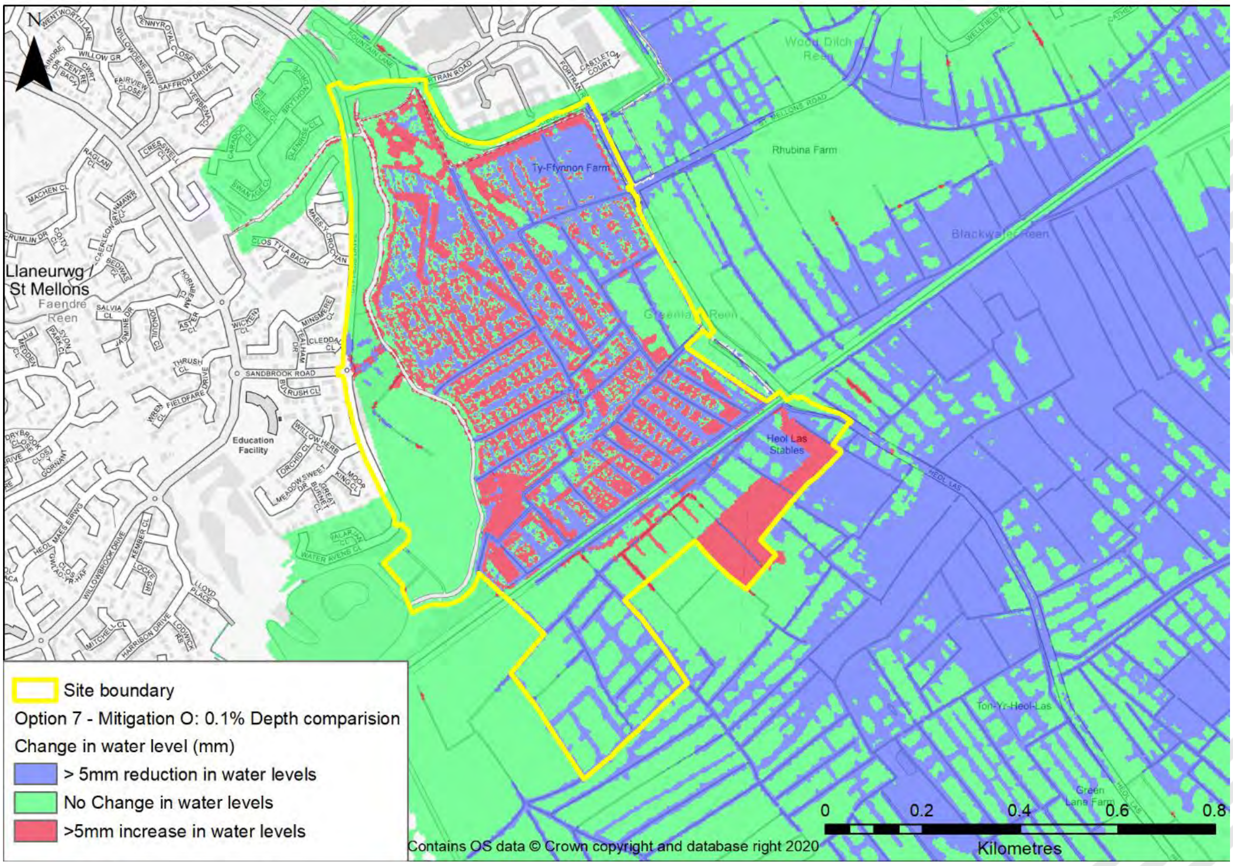


Figure 7-4 Pre and post development depth comparison - 0.1% AEP event

We therefore conclude that the proposed development site does not result in causing increased flood risk to others and provides a betterment in several areas.

7.9 Acceptability Criteria 9 [A1.14]

The development should be designed to be flood free during the 0.5% tidal event and 1% fluvial event, including an allowance for climate change.

Detailed flood modelling and a comprehensive strategy of flood mitigation has robustly demonstrated that all areas of proposed built development will be flood free in the 0.5% tidal event and 1% fluvial event, including an allowance for climate change. Flooding is limited to only those areas intentionally designed to hold and convey floodwater.

The scheme satisfies the requirements of this acceptability criteria.

7.10 Acceptability Criteria 10 [A1.15]

The development should be designed so that in an extreme 0.1% AEP event there would be less than 600mm of water on access roads and within the properties.

During the 0.1% AEP event (with the application of climate change for the tidal scenario) all areas of the built development site are predicted to be flood free. Flooding is limited to only those areas intentionally designed to hold and convey floodwater.

The scheme satisfies the requirements of this acceptability criteria.

8 Conclusions

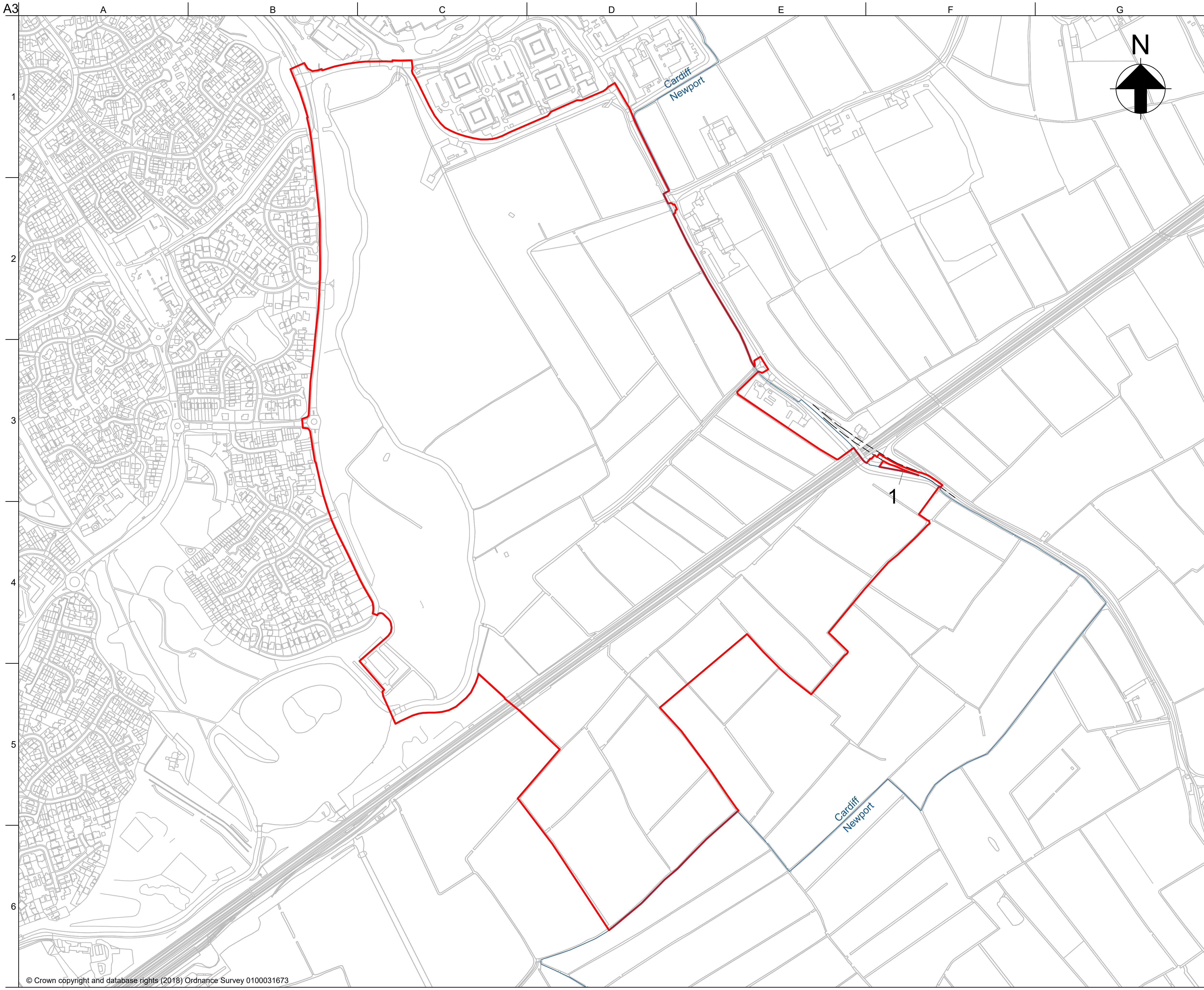
1. JBA Consulting were commissioned by ARUP to undertake a Flood Consequence Assessment (FCA) for a proposed development site at St Mellons Parkway, Newport.
2. The site is cross boundary with the majority of the proposed development located within Cardiff, however small parts of the site are located within Newport. This FCA has therefore been prepared in support of an Outline Planning Application (OPA) to Cardiff Council as well as in support of three separate Full Planning Applications (FPAs) to Newport City Council for works along the eastern boundary of the site.
3. The site is located in the St Mellons area of Cardiff and currently consists of grasslands. It is surrounded by housing to the west, St Mellons Business Park to the north and farmland to the south and east. The main railway line from Newport to Cardiff runs along the southern edge of the site.
4. The proposals are for a new business district of up to 90,000sqm of campus style employment floor space, together with the construction of a new transport interchange (including a train station) and ancillary development. The masterplan for the site is currently in the preliminary stages of preparation and a detailed site layout has not yet been determined. The assumed lifetime of the development is 75years.
5. The proposed development site is located within Zone C1 of Natural Resources Wales (NRW) Development Advice Map (DAM). Zone C1 describes areas at risk of flooding but served by significant infrastructure, including flood defences. Development can take place in C1 subject to application of the Justification Test and acceptability of the consequences.
6. The proposed development is allocated in the Cardiff Local Development Plan as a strategic site for employment and considered necessary to support key infrastructure improvements in the Cardiff Local Development Plan. The site help meets Key Policies 2,6,8 and 9 of the LDP. The site therefore meets the key objectives of the Justification Test.
7. The Cardiff Council Strategic Flood Consequence Assessment states that no significant problems are anticipated to the development of this site with respect to TAN-15.
8. The site is at little or no risk of flooding from reservoir, groundwater and surface water sources.
9. A risk of fluvial flooding was identified in the Cardiff Strategic Flood Consequence Assessment in 2012 which predicted widespread flooding to the site. This was based on high-level flood modelling of the area with many simplifications and assumptions. JBA's build of the SFCA model with new data and the latest modelling methods, have used this new modelling to inform a detailed assessment of fluvial and surface water flood risks.
10. The NRW Wentlooge tidal flood risk model, developed by JBA in 2014, has been used to assess tidal flood risk to the site during the 0.5% AEP and 0.1% AEP events. All events incorporate current predictions for climate change related sea level rise up to 2095. Residual flood risk to the site from a breach of the tidal defences that protect the Wentlooge levels has been assessed for the 0.1% AEP event with allowance for climate change.
11. To manage the risk of flooding, the proposed built development (buildings, roads and parking areas) will be raised to a minimum ground level of 6.0mAOD. This ground raising will be accompanied by the construction of a compensatory flood storage area to the south of the development to offset any loss of flood storage associated with the development proposals. It is proposed that Greenlane reen will be widened to 3m to improve conveyance of water and hydraulic controls are proposed on the two culverts under the railway line to prevent the ingress of tidal flood water into the site.
12. The tidal and pluvial flood modelling shows that the proposed built development will be flood free in all events, up to and including the 0.1% AEP pluvial event and the 0.1% AEP plus climate change tidal event.

13. In the very unlikely scenario of multiple breaches in the significant NRW coastal defences between Newport and Cardiff, the residual flood risk to the site remains well below the acceptability criteria (ie. flood depths <600mm) set out in TAN15.

14. The site provides safe access and egress through the primary (northern) and secondary (western) highways in all scenarios. Site occupants and business owners will be advised to sign up to NRW flood warnings.

15. Comprehensive flood modelling supports the conclusion that on the grounds of flood risk, the proposed development site is expected to be safe over its lifetime, meeting all of the requirements set out in TAN-15 and the aims of Planning Policy Wales.

Appendix A: Overall Site Boundary



Do not scale

N

Master Site Boundary (Area 80.25ha)

Local Authority Boundary

1 - Note, boundary follows alignment of western edge of Heol Las carriageway crossing reconstructed bridge. Not based on OS mapping, alignment on plan is approximate.

Issue	Date	By	Chkd	Appd
1	28/05/20	RC	DW	DB

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Client
Cardiff Parkway Developments Ltd

Job Title
Cardiff Hendre Lakes

Master Site Boundary

Scale at A3: 1:6,000 @ A3

Discipline: Urban Design

Job No: **252199-00**

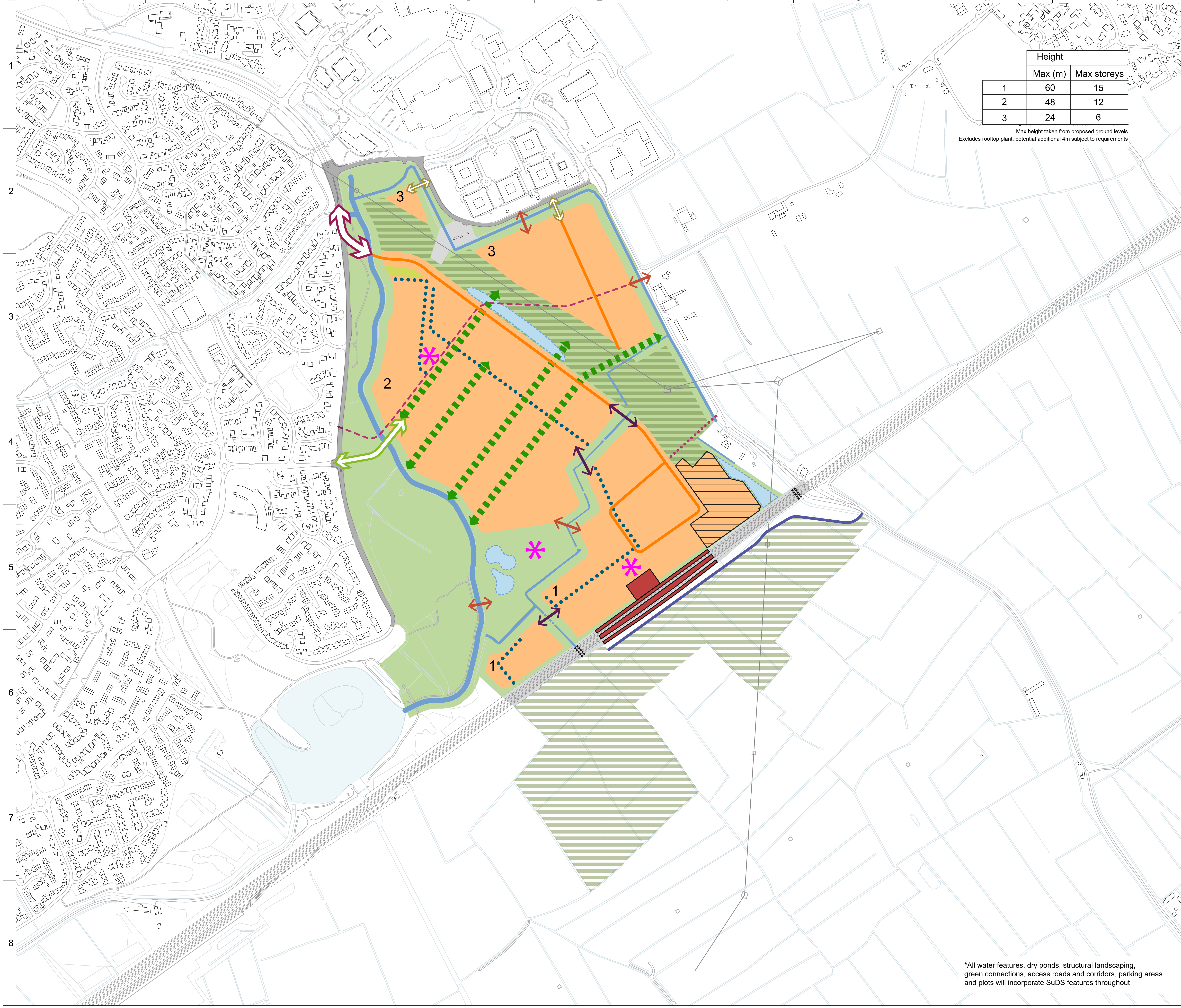
Drawing Status: **DRAFT**

Drawing No: **UD102**

Issue: **01**

Appendix B: Site Plan

A2



Height		
	Max (m)	Max storeys
1	60	15
2	48	12
3	24	6

Max height taken from proposed ground levels
Excludes rooftop plant, potential additional 4m subject to requirements

*All water features, dry ponds, structural landscaping, green connections, access roads and corridors, parking areas and plots will incorporate SuDS features throughout

Do not scale

Legend

- Planning application boundary (to be agreed)
- Retained reen
- Culverted reen
- Primary site access point
- Secondary site access point
- Vehicle access point
- Pedestrian crossing
- Vehicular crossing
- Main vehicular route
- Construction and emergency vehicular access
- Station building and platforms
- Surface parking for station
- Mitigation area for habitat north of rail line
- Ecological mitigation, access and agriculture
- Strategic green infrastructure and access*
- On-plot green connections (integrated SUDs)
- Strategic water feature*
- Dry ponds*
- Hendre Lake
- Location of existing primary reen culvert
- Proposed and enhanced diverted right of way
- Potential active travel link to Heol Las
- Development areas
- Key public spaces
- Plots
- Land in other uses (gas pumping station/ railway)
- Existing highway

Issue	Date	By	Chkd	Appd
01	16 / 06 / 20	RC	DW	SC

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www.arup.com

Client
CPDL

Project Title
CARDIFF HENDRE LAKES

Drawing Title
PARAMETER PLAN

1

0 100 200 250

Scale at A2
1:5,000

Discipline
Masterplanning

Drawing Status
ISSUE

Job No
252199-00

Issue
01

Name
PRX-ARP-ES-XX-DR-AX-001

Appendix C: Hydrology Calculation Record

Flood estimation report: St. Mellons

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

Approval

	Name and qualifications	Date
Method statement prepared by:	Lucy Archer-Lock BSc	22/08/2018
Method statement reviewed by:	Claire French BSc (Hons) MSc (Eng) MCIWEM CWEM CSci CEnv	07/09/2018
Calculations prepared by:	Lucy Archer-Lock BSc	22/08/2018
Calculations reviewed by:	Claire French BSc (Hons) MSc (Eng) MCIWEM CWEM CSci CEnv	07/09/2018

Revision History

Revision reference	Date issued	Amendments	Issued to
V1.0	03/04/2020	-	John Smith

Abbreviations

AM.................................. Annual Maximum

AREA .... Catchment area (km^2)

BFI .... Base Flow Index

BFIHOST .... Base Flow Index derived using the HOST soil classification

CFMP.............................. Catchment Flood Management Plan

CPRE.............................. Council for the Protection of Rural England

FARL............................... FEH index of flood attenuation due to reservoirs and lakes

FEH................................. Flood Estimation Handbook

FSR................................. Flood Studies Report

HOST .... Hydrology of Soil Types

NRFA .... National River Flow Archive

POT................................. Peaks Over a Threshold

QMED .... Median Annual Flood (with return period 2 years)

ReFH .... Revitalised Flood Hydrograph method

SAAR .... Standard Average Annual Rainfall (mm)

SPR................................. Standard percentage runoff

SPRHOST .... Standard percentage runoff derived using the HOST soil classification

Tp(0) .... Time to peak of the instantaneous unit hydrograph

URBAN .... Flood Studies Report index of fractional urban extent

URBEXT1990 .... FEH index of fractional urban extent

URBEXT2000 .... Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH .... Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

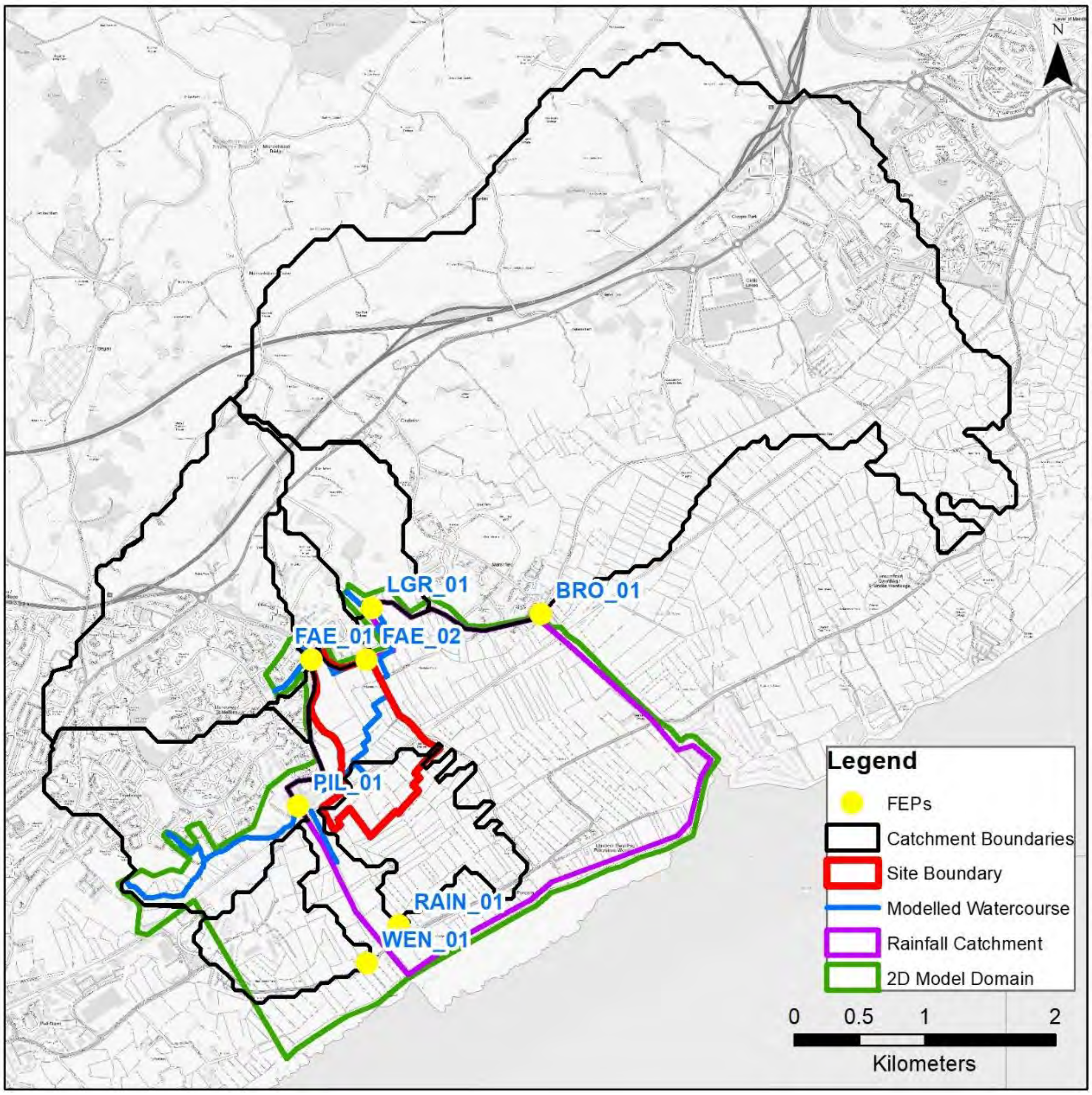
1.1 Requirements for flood estimates

Overview • Purpose of study • Peak flows or hydrographs? • Range of return periods and locations	The key purpose of the study is to investigate the fluvial flood risk as part of a Flood Consequence Assessment (FCA) for a development site on the outskirts of St Mellons, Cardiff. The site is known to be at risk from tidal flooding, and this has been investigated in a separate modelling study. An existing 1D-2D hydraulic model is being updated and used as the basis for this work. Design peak flow estimates and hydrographs will be derived for a range of return periods (2-year, 20-year, 30-year, 50-year, 100-year and 1000-year). The effects of climate change will be accounted for using the latest guidance[1]. Direct rainfall will be applied to the eastern portion of the modelled study area. A point inflow will be derived for the upstream catchments at 6 locations along the Reen network.

1.2 The catchment

Description Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.	There are several watercourses which drain the catchment, and a complex network of drainage ditches. St Mellons Pond is also a significant feature within the catchment. Pil-du-Reen drains the catchment in an easterly direction to St Mellons pond. Faendre Reen drains the catchment in a southerly direction to St Mellons pond. Topography is relatively flat in the lower parts of the catchment around the site of interest, but steeper in the upper parts of the catchment. The north-western parts of the catchment are urbanised. The southern parts of the catchment are rural. Soils in the lower parts of the catchment are predominantly loamy and clayey soils of coastal flats with naturally high groundwater. In the upper parts of the catchment, soils are mainly slightly acid loamy and clayey soils with impeded drainage. The British Geological Survey website[2] 1:50:000 scale mapping shows the upper parts of the catchment to be largely underlain by argillaceous rocks and sandstone in the upper parts of the catchment. South of the railway line, catchment geology predominantly comprises mudstone.

[1] https://gov.wales/climate-change-allowances-and-flood-consequence-assessments-cl-03-16
[2] http://mapapps.bgs.ac.uk/geologyofbritain/home.html

Map (Include river network, catchment boundary and gauging stations)


1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 6, released February 2018. This contains data up to water year 2015-16 for England, Wales and Northern Ireland and 28 gauges in Scotland and up to water year 2005-6 for the remaining gauges in Scotland.

1.4 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
No catchment gauges						

1.5 Other data available and how it has been obtained

Type of data	Data relevant	Data available	Source of data	Details

	to this study?	?		
Check flow gaugings (if planned to review ratings)	N/A	N/A	N/A	N/A
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.	Yes	No	Internet Search	The site is not located within NRW's historic flood outlines. In addition, no specific mention is made within the Cardiff Council Flood Risk Management Plan (FRMP) of any historical flooding across the proposed development site.
Flow or river level data for events	Yes	No	N/A	N/A
Rainfall data for events	Yes	No	N/A	N/A
Potential evaporation data	N/A	N/A	N/A	N/A
Results from previous studies	Yes	Yes	Cardiff SFCA Hydrological Assessment (Atkins 2012)	ReFH hydrographs scaled to FEH Statistical peak
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	N/A	N/A	N/A	N/A

Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The main site of interest is the St Mellons development site (NGR ST 24680 81500 at north of site). The main flood risk is predominantly thought to be from tidal sources. Tide-locking of watercourses may exacerbate fluvial flood risk.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	The catchment is fairly permeable. The upper parts of the catchment are fairly urbanised and the influence of St Mellons Pond needs to be considered.

1.6 Initial choice of approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	Yes
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-	Both the FEH Statistical and ReFH methods are suitable for flood flow estimation for the catchment. The catchment is not large, although parts of the catchment are heavily urbanised and the catchment is fairly permeable. The FEH Statistical and ReFH2 method will both be applied

catchments? If so, how?	and the results compared. Hydrographs shapes will be derived using the ReFH2 method. These will be fitted to the Statistical peaks if this is the preferred method. The catchment will be split into sub-catchments as detailed in Section **Error! Reference source not found.**. Direct rainfall will be applied to the development site and the lower parts of the catchment, south of the railway line. A point inflow will be applied to the upstream catchments. The catchment for RAIN_01 is being used as the descriptors to generate direct rainfall. ReFH2 is likely to be the preferred approach as a combination of direct rainfall and point inflows are being applied to the model. This will ensure a consistent storm is applied. The intervening area between the flow estimation points will be used to generate lateral inflows to be input to the hydraulic model.
Software to be used (with version numbers)	FEH Web Service / WINFAP-FEH v3.0.003[3] / ReFH2.2

[3] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

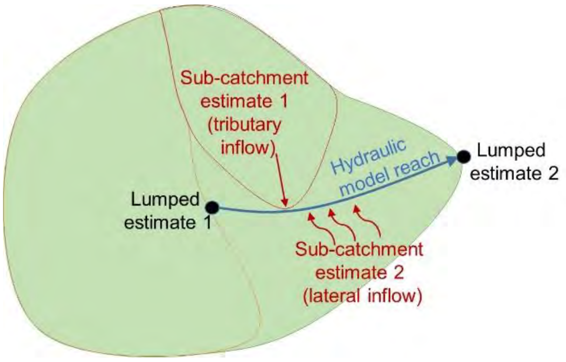
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
RAIN_01	L	-	Rainfall catchment descriptors	325350	179500	1.14	-
WEN_01	L	Wentlooge Levels	Remaining catchment around Wentlooge levels	325100	179200	0.90	-
FAE_01	L	Faendre Reen	Catchment at upstream model extent	324650	181450	3.00	-
PIL_01	L	Pil-du-Reen	Catchment to direct rainfall catchment	324900	180700	2.21	2.09
FAE_02	L	Faendre Reen	Catchment to direct rainfall catchment	325100	181450	6.03	5.63
LGR_01	L	Little Greenlane Reen	Catchment at upstream model extent	325650	181550	1.23	0.97
BRO_01	L	Drenewydd Reen/Broadway Reen	Catchment of Drenewydd Reen upstream model extent	326450	181950	14.84	15.21

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Values highlighted in red are those that have been updated.

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
RAIN_01	1.0	0.47	0.733	1.19	6.2	967	0.000	0.915
WEN_01	1.0	0.47	0.732	1.06	4.3	963	0.000	0.765
FAE_01	1.0	0.47	0.629	1.55	35.6	1060	0.261	0.142
PIL_01	1.0	0.47	0.678	1.56	17.4	1007	0.208	0.4334

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
FAE_02	1.0	0.47	0.652	2.83	26.4	1035	0.180	0.2923
LGR_01	1.0	0.47	0.649	0.96	26.3	1033	0.036	0.3367
BRO_01	0.985	0.47	0.695	3.76	43.5	1040	0.041	0.243

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The catchment boundary was exported from the FEH CD-ROM, and compared to terrain 50, contour mapping, and watercourse lines. The catchment boundaries seem largely consistent with the terrain 50 data. There is a complicated network of Reens and in some places it is likely the FEH catchment does not account for these correctly. This is considered in more detail in Section 6.2. A combination of point inflows and direct rainfall are being applied to the hydraulic model. Direct rainfall is being applied to the southern part of the catchment, including the site of interest. The catchment boundaries for PIL_01, FAE_02 and LGR_01 were updated to remove the areas where direct rainfall is being applied to ensure there was no double counting. The catchment boundary for BRO_01 was extended to include all the area up to where direct rainfall is being applied.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	A qualitative check of the FEH BFIHOST values was undertaken by comparing them to the geology and soils detailed in Section **Error! Reference source not found.**. The BFIHOST values range from 0.629 to 0.733. The values are supported by the geology and soils shown to underlie the catchment and have not been changed. The FEH FARL value ranges from 0.858 to 1.00. The FARL value is lower for the lower parts of the catchment which accounts for St Mellons Pond. The FARL values for the catchments including St Mellons Pond have been changed to 1.0 to exclude the attenuation effect of this water body as the pond is represented in the hydraulic model. The rest of the FEH values seem sensible and have not been changed. For the catchments where the area was adjusted, DPLBAR was updated according to equation 7.1 of the FEH Vol. 5, with the exponent set to the ratio of log DPLBAR and log AREA for the corresponding FEH catchment. Having revised the catchment boundaries, URBEXT for these catchments was updated using $URBAN_{50k}$ method. URBEXT2000 = URBAN50K * 0.629 The FEH URBEXT 2000 values for the other catchments have been updated to reflect changes in urbanisation to current conditions (2018).
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000 OS50k method

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m^3/s)	Final method	Data transfer: NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor: Weight	If more than one donor: Weighted ave. adjustment	Urban adjust-ment factor UAF	Final estimate of of QMED (m^3/s)
RAIN_01	0.3	CD	N/A	N/A	N/A	N/A	N/A	1.00	0.3
WEN_01	0.2	CD	N/A	N/A	N/A	N/A	N/A	1.00	0.2
FAE_01	1.1	CD	N/A	N/A	N/A	N/A	N/A	1.45	1.5
PIL_01	0.3	CD	N/A	N/A	N/A	N/A	N/A	1.40	0.8
FAE_02	1.3	CD	N/A	N/A	N/A	N/A	N/A	1.32	2.1
LGR_01	0.4	CD	N/A	N/A	N/A	N/A	N/A	1.06	0.4
BRO_01	3.0	CD	N/A	N/A	N/A	N/A	N/A	1.08	3.2

Are the values of QMED spatially consistent?	Yes
Method used for urban adjustment for subject and donor sites	WINFAP-FEH V4

Parameters used for WINFAP v4 urban adjustment if applicable

Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
N/A	N/A	N/A

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[4] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Include a map if necessary. Note that donor catchments should usually be rural.	Gauged catchments within the hydrometric areas surrounding the study catchment were assessed for suitability for data transfer to the study watercourses. 5 donor stations within 40km of the subject site were assessed. All were rejected due to dissimilar catchment descriptors (particularly due to the small area of the study catchment and much higher SAAR values) and/or not being classed as suitable for data transfer by the NFRA.

[4] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
No suitable donor stations						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
FAE_02	FAE_02	No	Reviewed and retained: • 27073 (Brompton Beck @ Snainton Ings) • 20002 (West Peffer Burn @ Luffness) • 76011 (Coal Burn @ Coalburn) Removed: • 49005 (Bollingey Stream @ Bollingey Cocks Bridge) – less than eight years of data	L-CV: 0.228 L-skew: 0.215
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
RAIN_01	P	FAE_02	GL – both GL and GEV give an acceptable fit. GL closer to 0 and is the recommended distribution for UK catchments.	V4 urban adjustment applied. No requirement for permeable adjustment as most stations in the pooling group have SPRHOST >20%.	Location: 1.000 Scale: 0.229 Shape: -0.215	2.80
WEN_01					Location: 1.000 Scale: 0.229 Shape:-0.215	2.80
FAE_01					Location: 1.000 Scale: 0.190 Shape: -0.261	2.69
PIL_01					Location: 1.000 Scale: 0.197 Shape: -0.252	2.71

Site code	**Method** (SS, P, ESS, J)	**If P, ESS or J, name of pooling group (**Error! Reference source not found.**)**	**Distribution used and reason for choice**	**Note any urban adjustment or permeable adjustment**	**Parameters of distribution** (location, scale and shape after adjustments)	**Growth factor for 100-year return period**
FAE_02					Location: 1.000 Scale: 0.201 Shape: -0.247	2.72
LGR_01					Location: 1.000 Scale: 0.223 Shape: -0.221	2.78
BRO_01					Location: 1.000 Scale: 0.223 Shape: -0.222	2.78

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	**Flood peak (m^3/s) for the following return periods (in years)**					
	2	**20**	**30**	**50**	**100**	**1000**
RAIN_01	0.3	0.5	0.5	0.6	0.7	1.2
WEN_01	0.2	0.4	0.4	0.5	0.6	1.0
FAE_01	1.5	2.8	3.1	3.5	4.1	7.2
PIL_01	0.8	1.5	1.7	1.9	2.2	3.8
FAE_02	2.1	3.9	4.3	4.9	5.7	9.8
LGR_01	0.4	0.7	0.8	0.9	1.1	1.8
BRO_01	3.2	6.2	6.8	7.6	8.9	14.9

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Catchment sub-divisions for ReFH2 model

Site code	Area (km^2)		Only relevant if significant transfers of water via sewers crossing catchment boundaries…	
	Rural or undeveloped	Paved	Paved with sewers draining out of topographic catchment	Paved outside topographic catchment with sewers draining into catchment
RAIN_01	1.14	0	N/A	N/A
WEN_01	0.9	0	N/A	N/A
FAE_01	1.77	1.23	N/A	N/A
PIL_01	1.41	0.68	N/A	N/A
FAE_02	4.04	1.59	N/A	N/A
LGR_01	0.92	0.05	N/A	N/A
BRO_01	14.23	0.98	N/A	N/A
Sources of information for creating sub-divisions	N/A		**Sewer capacity** (return period / rainfall intensity / flow rate) and source of information	N/A
Link to map or shapefile of subdivisions	N/A			

4.2 Parameters for ReFH2 model

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR
RAIN_01	CD	2.81	1.41	698.82	70	37.71	2.17
WEN_01	CD	2.95	1.48	697.01	70	36.74	2.17
FAE_01	CD	1.87	0.94	533.39	70	36.41	1.82
PIL_01	CD	2.36	1.18	605.79	70	38.16	1.99
FAE_02	CD	2.91	1.46	566.23	70	42.43	1.90
LGR_01	CD	1.57	0.79	561.83	70	33.43	1.89
BRO_01	CD	2.92	1.46	633.14	70	46.93	2.04
Brief description of any flood event analysis carried out (further details should be given in the annex)				N/A			
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

4.3 Design events for ReFH2 method

Site code	Season of design event (summer or winter)*	Storm duration (hours)	Storm area for ARF (if not catchment area)	Source of design rainfall statistics (FEH99 or FEH13)
RAIN_01	Summer	5.50	N/A	FEH13
WEN_01	Summer	5.50	N/A	FEH13
FAE_01	Summer	3.75	N/A	FEH13
PIL_01	Summer	4.50	N/A	FEH13
FAE_02	Summer	5.50	N/A	FEH13
LGR_01	Summer	3.25	N/A	FEH13
BRO_01	Summer	5.50	N/A	FEH13
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Yes. Individual storm durations have been used to generate peak flow estimates for comparison with the FEH Statistical method estimates. For application to the hydraulic model, a uniform storm duration of 5.50 hours and areal reduction factor (ARF) will be used.	

*Summer was chosen as the season of the design event following testing in the hydraulic model on the 20-year and the 100-year event.

4.4 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m^3/s) for the following return periods (in years)					
	2	20	30	50	100	1000
RAIN_01	0.2	0.4	0.5	0.5	0.6	1.3
WEN_01	0.2	0.3	0.4	0.3	0.5	1.0
FAE_01	1.5	2.9	3.1	3.5	4.1	8.0
PIL_01	0.8	1.4	1.5	1.7	2.0	3.9
FAE_02	1.8	3.3	3.6	4.0	4.8	9.3
LGR_01	0.4	0.7	0.8	0.9	1.0	2.1
BRO_01	3.4	6.3	6.9	7.8	9.3	18.8

4.5 Direct Rainfall

For the RAIN_01 catchment, flows will be added to the model as direct rainfall rather than point inflows. The net rainfall from the ReFH2 flow estimates will be applied to the model.

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH2	ReFH2
RAIN_01	0.86	0.88
WEN_01	0.82	0.82
FAE_01	0.98	1.00
PIL_01	0.91	0.91
FAE_02	0.87	0.84
LGR_01	0.91	0.97
BRO_01	1.06	1.04

5.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	ReFH2 is the preferred method for generating the design peak flow estimates for the study catchment. A combination of point inflows and direct rainfall will be applied to the hydraulic model, and therefore using this method will ensure a consistent storm is applied across the catchment.
How will the flows be applied to a hydraulic model? If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?	A combination of point inflows and direct rainfall will be applied to the hydraulic model. Point inflows will be applied for all catchments except RAIN_01, where direct rainfall will be applied instead. An intervening area hydrograph will be generated for FAE_02 using catchment descriptors generated for the intervening area.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: • FEH catchments had to be reshaped to avoid double counting in the areas where direct rainfall was being applied to the model. • Simple approach used as not much data was available • There is no clear choice for a donor to adjust the FEH Statistical method QMED estimate and that using catchment descriptors alone is preferable. • The pooling group used to define the growth curve for the FEH Statistical method is representative of the catchment. • The ReFH2 model hydrograph shape is representative of the catchment.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	• The main limitation is the lack of catchment specific hydrometric data to improve the QMED estimate. • The FEH Statistical method has been applied for large AEP events beyond the range used to calibrate this model.

Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	It is not possible to directly quantify the uncertainty for the ReFH2 method. There is no method provided in the FEH for estimating uncertainty for the common situation of an ungauged catchment, pooled growth curve and QMED estimated from catchment descriptors. The uncertainty will depend on many factors, for example, how unusual the study catchment is relative to the pooling group, and the uncertainty in flow measurement at other gauges. A UK average measure of uncertainty is presented in a technical guidance report[5] generated by a R&D project into the FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others). The report presents results for rural catchments ($URBEXT_{2000}$ <0.03) and moderately urbanised catchments (0.03 ≤ $URBEXT_{2000}$ < 0.15). The 95% confidence limits for a 1% AEP flood estimate for a rural catchment are: • Without donor adjustment of QMED: 0.45 – 2.23 times the best estimate • With donor adjustment of QMED (one donor): 0.47 – 2.12 times the best estimate The 95% confidence limits for a 1% AEP flood estimate for a moderately urbanised catchment are: • Without donor adjustment of QMED: 0.33 – 3.01 times the best estimate • With donor adjustment of QMED (one donor): 0.34 – 2.94 times the best estimate.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The design peak flow estimates and hydrographs have been derived for the purposes of this modelling study. If peak flow estimates and hydrographs are required for different purposes it is recommended that, at a minimum, a review of the results is carried out.
Give any other comments on the study, e.g. suggestions for additional work.	No further comments.

5.4 Checks

Are the results consistent, for example at confluences?	Yes flows increase downstream (e.g. FAE_01 and FAE_02).
What do the results imply regarding the return periods of floods during the period of record?	There is no local flow data (within the study area) against which to compare the design peak flow estimates.
What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factor range for the methods is: • FEH Statistical: 2.69-2.80 • ReFH2: 2.71-2.94 The typical range is 2.1 – 4.0. All values are within the typical range.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1%:1% AEP event growth factor range for the methods is: • FEH Statistical: 1.67-1.74 • ReFH2: 1.93-2.08
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	The current study peak flow estimates are preferred to the flows from the Cardiff SFCA as the latest methods, data and software have been used. The flows from this study are not directly comparable with the flows from the SFCA assessment as some of the catchment boundaries (PIL_01, FAE_02 and LGR_01) for this study were updated to

[5] Environment Agency. 2017. Using local data to reduce uncertainty in flood frequency estimation.

remove areas where direct rainfall is being applied and the catchment differ.

The specific discharge for similar catchments between the studies were compared to give an indication of how the flows between the two studies compare.

Table 5-1: JBA final results specific discharge for selected catchments

Catchment	Area (km^2)	100 year flow (m^3/s) (ReFH2 final 5.5 hour duration)	Specific discharge($m^3/s/km^2$)
PIL_01	2.1	2.0	1.0
FAE_01	3.0	4.1	1.4
LGR_01	1.0	1.1	1.1

Table 5-2: SFCA final results specific discharge for selected catchments

Catchment	Area (km^2)	100 year flow (m^3/s) – 6.5 hour duration	Specific discharge($m^3/s/km^2$)
Greenlane1	0.9	1.1	1.2
Pil_du1	0.7	0.8	1.0
Pil_du2	0.6	0.8	1.4
Pil_du3	0.7	0.8	1.1
Faendre1	0.2	0.3	1.3
Faendre2	1.6	2.0	1.2
Faendre3	1.5	2.1	1.4

This shows that for the specific discharge for PIL_01 is slightly lower than the Pil_du catchments from the SFCA, and LGR_01 is slightly lower than Greenlane1. For FAE_01, the specific discharge is comparable to the Faendre catchments from the SFCA.

Are the results compatible with the longer-term flood history?	Although flooding has been reported, there is no local gauge data against which to compare the design flow estimates.
Describe any other checks on the results	Modelled levels and flood extents will be sensibility-checked to ensure that flow inputs result in realistic outputs.

5.5 Final results

The results in the table below are based on a uniform storm duration of 5.5 hours, and therefore differ slightly to the results in Section 4. The flows for FAE_02 will be applied to the model using the intervening area catchment that covers the FAE_02 catchment downstream of FAE_01.

Site code	Flood peak (m^3/s) for the following return periods (in years)					
	2	20	30	50	100	1000
RAIN_01	0.2	0.4	0.5	0.5	0.6	1.3
WEN_01	0.2	0.3	0.4	0.4	0.5	1.0
FAE_01	1.6	2.8	3.1	3.4	4.1	7.7
PIL_01	0.8	1.4	1.5	1.7	2.0	3.9
FAE_02	1.9	3.4	3.7	4.1	4.9	9.5
LGR_01	0.4	0.7	0.8	0.9	1.1	2.2
BRO_01	3.5	6.5	7.2	8.1	9.7	19.7

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Q0002.csv Q0020.csv Q0100.csv Q1000.csv

6 Annex

6.1 Final pooling group (FAE_02)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.108	35	0.82	0.2	0.049	0.933
20002 (West Peffer Burn @ Luffness)	2.994	41	3.299	0.292	0.015	3.624
76011 (Coal Burn @ Coalburn)	3.019	39	1.84	0.164	0.316	1.788
203046 (Rathmore Burn @ Rathmore Bridge)	3.15	34	10.788	0.146	0.136	0.821
45816 (Haddeo @ Upton)	3.185	23	3.456	0.307	0.418	1.166
27051 (Crimple @ Burn Bridge)	3.202	44	4.539	0.223	0.156	0.489
25003 (Trout Beck @ Moor House)	3.218	43	15.164	0.17	0.288	0.639
28033 (Dove @ Hollinsclough)	3.277	37	4.2	0.237	0.418	0.843
72014 (Conder @ Galgate)	3.296	49	16.646	0.212	0.082	0.361
47022 (Tory Brook @ Newnham Park)	3.296	23	7.123	0.262	0.115	1.056
49003 (de Lank @ de Lank)	3.307	50	13.985	0.225	0.217	0.223
26802 (Gypsey Race @ Kirby Grindalythe)	3.337	17	0.116	0.274	0.24	0.207
73015 (Keer @ High Keer Weir)	3.391	25	12.239	0.174	0.191	0.335
25019 (Leven @ Easby)	3.391	38	5.333	0.338	0.391	1.514
Total		498				
Weighted means		498		0.228	0.215	

6.2 Catchment definition

Due to the complicated nature of the catchment and the Reen network, there is significant uncertainty in the catchment boundaries. The FEH webservice catchment boundaries were compared to LiDAR where available, terrain 50, contour, OS mapping and watercourse lines.

For the BRO_01 catchment, it was found that, in the south and east of the catchment, the FEH catchment boundary incorrectly cuts across the Reen network. A revised catchment was created, using contour lines and the mapped reen network, as shown in Figure 6-1. In BRO_01_revised, land to the south of the railway line is assumed to discharge into Broadway Reen and into the Severn estuary rather than towards the study area

The FEH BRO_01 catchment has an area of 15.20km^2, whereas the revised catchment has an area of 14.50km^2. As the catchment boundary definition is still highly uncertain, it was decided to retain the BRO_01 catchment as this adopts a conservative approach.

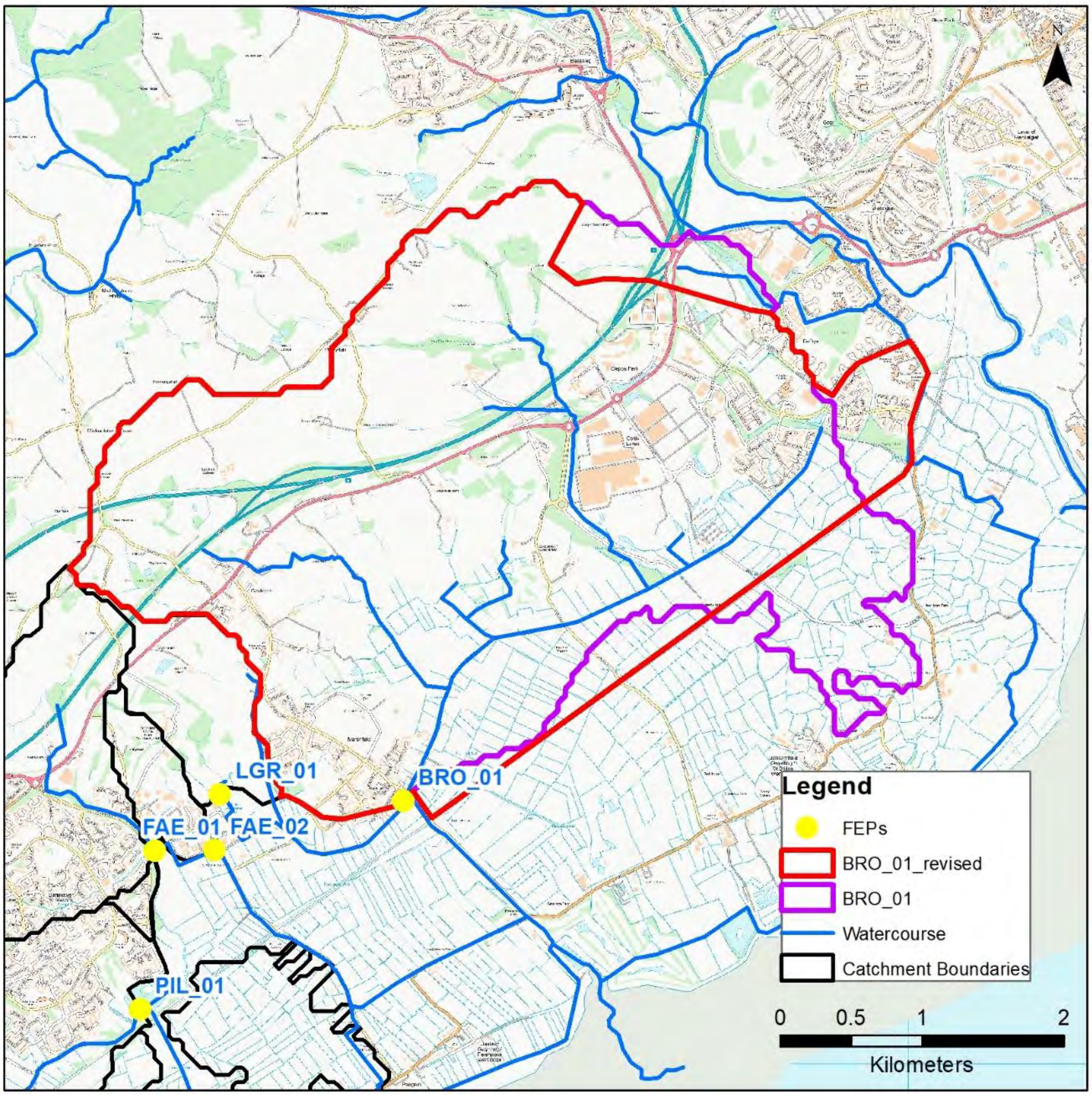


Figure 6-1: BRO_01 Catchment definition

Appendix D: Modelling Technical Report

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
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Thirsk
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