



Land behind Sion Chapel, Pontfadog, LL20 7AS

TAN15: Flood Consequence Assessment

For Gareth Morris Construction

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Land behind Sion Chapel, Pontfadog, LL20 7AS

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EXECUTIVE SUMMARY

A residential development, would be expected to remain dry in all but the most extreme conditions. Providing the recommendations made in this FCA are instigated, flood risk from all sources would be minimised, the consequences of flooding are acceptable, and the development would be in accordance with the requirements of TAN15.

This FCA demonstrates that the proposed development would be operated with minimal risk from flooding, would not increase flood risk elsewhere and is compliant with the requirements of TAN15. The development should not therefore be precluded on the grounds of flood risk.

1.0 INTRODUCTION

1.1 Background

This Flood Consequence Assessment (FCA) has been prepared by KRS Environmental Limited to support a planning application for the proposed development at Land behind Sion Chapel, Pontfadog, LL20 7AS. This FCA includes an assessment of the existing and proposed surface water drainage of the site.

This FCA has been carried out in accordance with guidance contained in Technical Advice Note 15 Development and Flood Risk (TAN15) and associated Development Advice Maps. This FCA identifies and assesses the risks of all forms of flooding to and from the development and demonstrates how these flood risks will be managed so that the development remains safe throughout the lifetime, taking climate change into account.

It is recognised that developments which are designed without regard to flood risk may endanger lives, damage property, cause disruption to the wider community, damage the environment, be difficult to insure and require additional expense on remedial works. The development design should be such that future users will not have difficulty obtaining insurance or mortgage finance, or in selling all or part of the development, as a result of flood risk issues.

1.2 Technical Advice Note 15 (TAN15)

One of the key aims of TAN15 is to ensure that flood risk is taken into account at all stages of the planning process; to avoid inappropriate development in areas at risk of flooding and to direct development away from areas of highest risk.

It advises that where new development is exceptionally necessary in areas of higher risk, this should be safe, without increasing flood risk elsewhere, and where possible, reduce flood risk overall.

A risk based approach is adopted at stages of the planning process, applying a source pathway receptor model to planning and flood risk. To demonstrate this, an FCA is required and should include:

- whether a proposed development is likely to be affected by current or future flooding from all source;
- whether it will increase flood risk elsewhere;
- whether the measures proposed to deal with these effects and risks are appropriate; and
- satisfy the justification test, including the acceptability of consequences.

1.3 Justification Test

The Justification Test sets out the details required to justify siting a new development in an area believed to be at risk of flooding and is defined in Section 6 of TAN15. The required criteria a site / development must fulfil are;

- i) 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
- ii) 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

- iii) it concurs with the aims of PPW and meets the definition of previously developed land; and,
- iv) the potential consequences of a flooding event for the particular type of development have been considered, and in terms of the criteria contained in sections 5 and 7 and appendix 1 found to be acceptable.

1.4 Report Structure

This FCA has the following report structure:

- Section 2 describes the location area and the existing and proposed development;
- Section 3 outlines the flood risk to the existing and proposed development;
- Section 4 details the proposed surface water drainage for the site and assesses the potential impacts of the proposed development on surface water drainage;
- Section 5 details the proposed foul water drainage of the site;
- Section 6 outlines mitigation measures used to reduce the overall level of flood risk;
- Section 7 details the Justification Test; and
- Section 8 presents a summary and conclusions.

2.0 LOCATION & DEVELOPMENT DESCRIPTION

2.1 Site Location

The site is located on Land behind Sion Chapel, Pontfadog, LL20 7AS (see Figure 1).

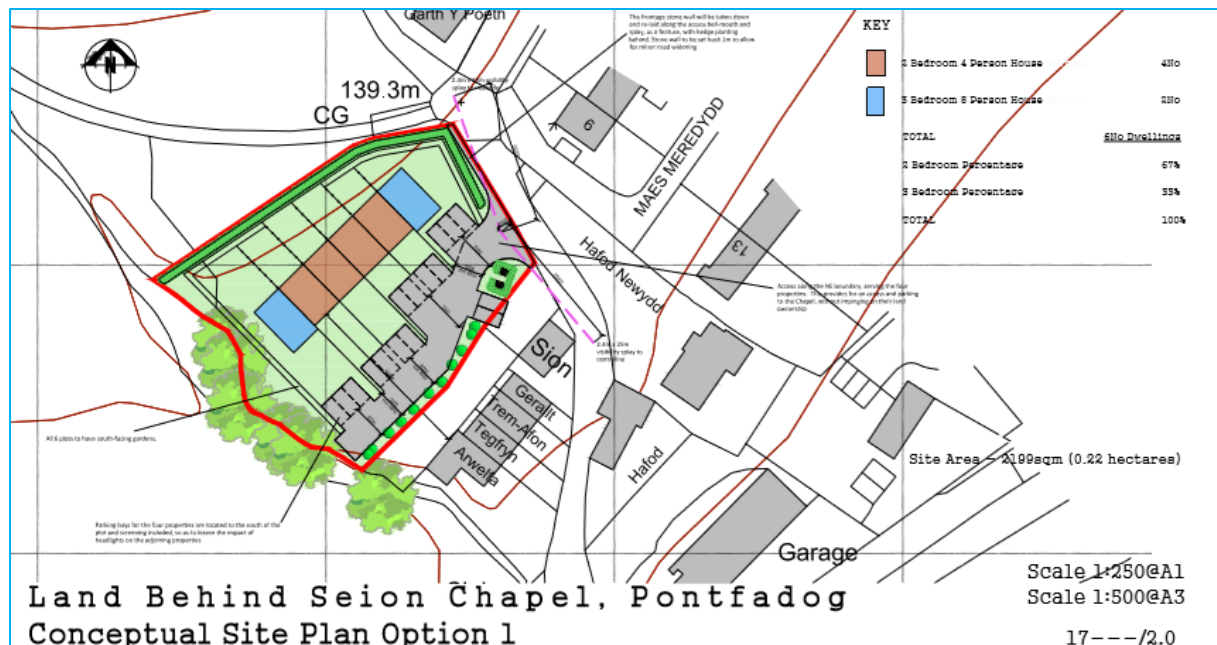


Figure 1 - Site Location

2.2 Existing Development

The site is currently in a greenfield state.

2.3 Proposed Development

The proposals are for 6 houses, as shown in Figure 1. Further details with regard to the proposed development can be found in the accompanying information submitted with the planning application.

2.4 Ground Levels

The site falls from north to south with ground levels between 139 metres Above Ordnance Datum (mAOD) and 130mAOD.

2.5 Catchment Hydrology

A small unnamed watercourse is located to the east of the site.

2.6 Geology

The British Geological Survey (BGS) Map indicates that the superficial deposits consist of Glaciofluvial Sheet Deposits, Devensian - sand and gravel. Superficial deposits formed up to 2 million years ago in the Quaternary Period in a local environment previously dominated by ice age conditions (UGF) and Alluvium - clay, silt, sand and gravel. Superficial deposits formed up to 2 million years ago in the Quaternary Period in a local environment previously dominated by rivers (U).

The bedrock deposits consist of the Elwy Formation - mudstone, siltstone and sandstone. Sedimentary bedrock formed approximately 424 to 427 million years ago in the Silurian Period in a local environment previously dominated by deep seas.

2.7 Soil

Information from the National Soil Resource Institute¹ details the site area as being situated on freely draining acid loamy soils over rock. The Wallingford Winter Rain Acceptance Potential (WRAP) map indicates that the site lies within WRAP Class 2: i) Very permeable soils with shallow ground water; ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils; and iii) Moderately permeable soils, some with slowly permeable subsoils.

2.8 Permeability / Infiltration Rate

In determining the future surface runoff from the site, the potential of using infiltration devices has been considered. An overview of the general ground conditions may be used to gauge if there is potential for their application. The general ground conditions suggest that the permeability and infiltration rate of the site will be moderate and infiltration devices such as soakaways will work at the site.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations. Such work is beyond the scope of this FCA but should be undertaken to inform the detailed drainage strategy for the site.

¹ <https://www.landis.org.uk/soilscapes/>

3.0 FLOOD RISK

3.1 Sources of Flooding

All sources of flooding have been considered, these are: fluvial (river) flooding, tidal (coastal) flooding, groundwater flooding, surface water (pluvial) flooding, sewer flooding and flooding from artificial drainage systems/infrastructure failure.

The key consequences of flooding are death/personal injury, extensive damage to property, properties uninhabitable for long periods, properties cannot be sold, insurance unavailable or too expensive, expense of installing flood resilience measures and business interruptions.

3.2 Natural Resources Wales Flood Zones

A review of Natural Resources Wales Flood Zones indicates that the site is located within Flood Zone 1 and therefore has a 'low probability' of flooding as shown in Figure 2, with less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%) (see Table 1).

The Flood Zones are the current best information on the extent of the extremes of flooding from rivers or the sea that would occur without the presence of flood defences, because these can be breached, overtopped and may not be in existence for the lifetime of the development. The Natural Resources Wales Flood Zones show the worst-case scenario.

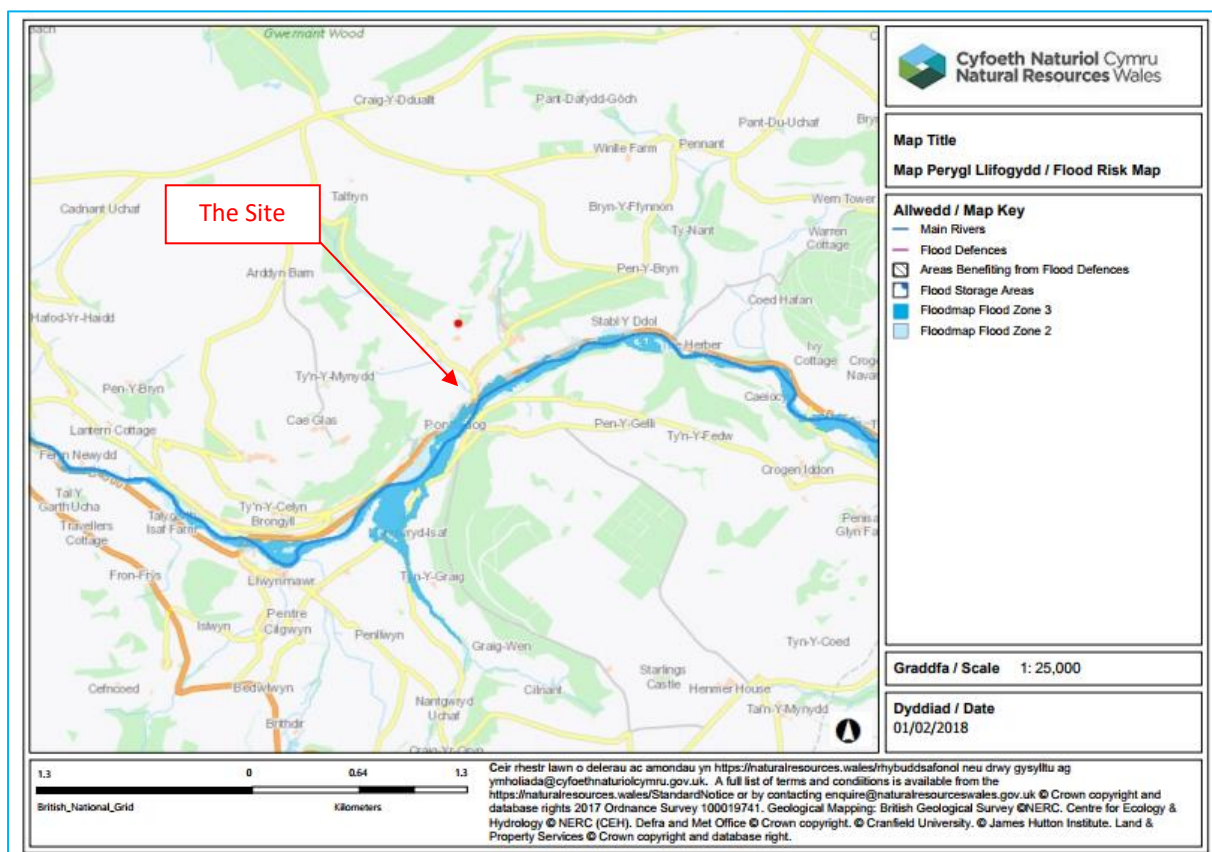


Figure 2 - Natural Resources Wales Flood Zones

Table 1 - Natural Resources Wales Flood Zones and Appropriate Land Use

Flood Zone	Probability	Explanation	Appropriate Land Use
Zone 1	Low	Less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%)	All development types generally acceptable
Zone 2	Medium	Between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year	Most development type are generally acceptable
Zone 3a	High	A 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year	Some development types not acceptable
Zone 3b	'Functional Floodplain'	Land where water has to be flow or be stored in times of flood. SFRAs should identify this zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1% flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes)	Some development types not acceptable

3.3 Development Advice Map

The Development Advice Map (DAM) which accompanies TAN15 shows that the site is located within Zone B - Areas known to have been flooded in the past evidenced by sedimentary deposits (see Figure 3). This is used as part of a precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. If site levels are greater than the flood levels used to define adjacent extreme flood outline there is no need to consider flood risk further.

However, it should be noted that this historical flooding normally relates to flooding which occurred in the geological past i.e. many thousands of years ago and has been identified from the local geology therefore, it does not give a good indication of recent historical flooding and/or flood risk.

Table 2 describes the composition and use of the TAN15 zones to control and manage development. Applying the Flood Risk Vulnerability Classification in Figure 2 of TAN15, the proposed development is classified as 'highly vulnerable'.

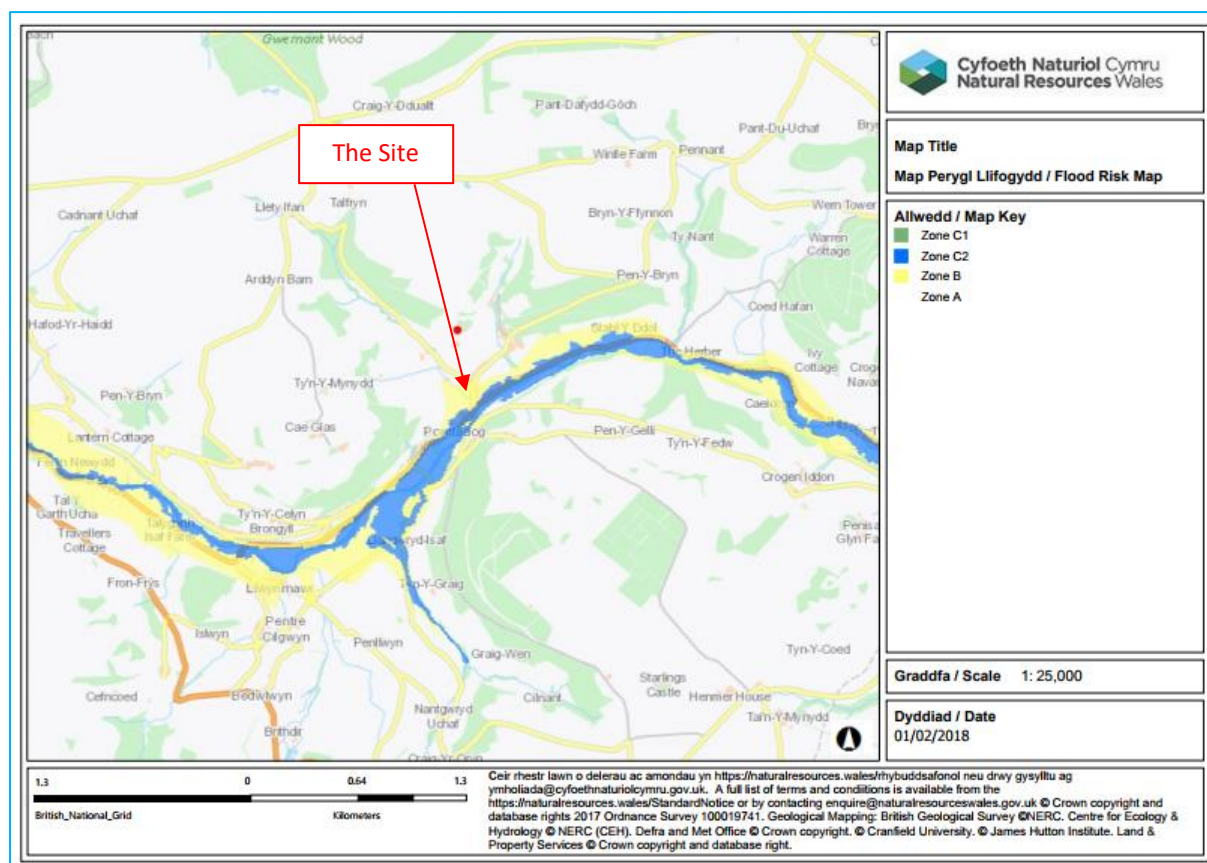


Figure 3 - Development Advice Map

Table 2 - TAN15 Flood Zones

Description of Zone	Zone	Use within the precautionary Framework
Considered to be at little or no risk of fluvial or tidal/coastal flooding.	A	Used to indicate that justification test is not applicable and no need to consider flood risk further.
Areas known to have been flooded in the past evidenced by sedimentary deposits.	B	Used as part of a precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. If site levels are greater than the flood levels used to define adjacent extreme flood outline there is no need to consider flood risk further.
Based on Environment Agency extreme flood outline, equal to or greater than 0.1% (river, tidal or coastal)	C	Used to indicate that flooding issues should be considered as an integral part of decision making by the application of the justification test including assessment of consequences.
Areas of the floodplain which are developed and served by significant infrastructure, including flood defences.	C1	Used to indicate that development can take place subject to application of justification test, including acceptability of consequences.
Areas of the floodplain without significant flood defence infrastructure.	C2	Used to indicate that only less vulnerable development should be considered subject to application of justification test, including acceptability of consequences. Emergency services and highly vulnerable development should not be considered.

3.4 Historic Flooding

There are no records of anecdotal information of flooding at the site including within the British Hydrological Society “Chronology of British Hydrological Events”. No other historical records of flooding for the site have been recorded. Therefore, it has been concluded that the site has not flooded within the recent past.

3.5 Existing and Planned Flood Defence Measures

The site is not protected against flooding by flood defence measures. Further mitigation measures will be used to protect the site from flooding these are discussed in Section 5.0.

3.6 Climate Change

Projections of future climate change, in the UK, indicate more frequent, short-duration, high intensity rainfall and more frequent periods of long duration rainfall. Guidance included within TAN15 recommends that the effects of climate change are incorporated into FCA. Recommended precautionary sensitivity ranges for peak rainfall intensities and peak river flows are outlined in the CL-03-16 - Climate change allowances for Planning purposes.

Table 3 show the peak river flow allowances by river basin district. There is reasonable level of certainty that the future impacts of climate change will lie somewhere between the central and upper allowances. The 9th January 2014 Welsh Government letter to all Chief Planning Officers (CPO) in Wales and CL-03-16 - Climate change allowances for Planning purposes clarifies and refers to the Natural Resources Wales recommendations that the lifetime of development for residential development is 100 years i.e. 2118.

Table 3 - Peak River Flow Allowances by River Basin District (use 1961 to 1990 baseline)

River basin district	Allowance category	2015 to 2039	2040 to 2059	2060 to 2115
Severn	Upper end	+ 25%	+ 40%	+ 70%
	High central	+ 10%	+ 20%	+ 25%
	Central	+ 0%	+ 5%	+ 5%

3.7 Fluvial (river) Flooding

The fluvial flood risk can be considered to be limited due to the difference in elevations between the site and the identified watercourse. The ground levels of the site are a minimum of 2.00m above the normal water level of the watercourse. Flood risk to the site from the watercourse can also be considered to be limited, since the watercourse is located on the boundaries of the site well away from the proposed buildings. Any overbank flow would follow the contours of the surrounding area and would flow directly away from the site rather than flowing towards the site.

A review of the Natural Resources Wales Flood Zones indicates that the site is located within Flood Zone 1 and therefore has a ‘low probability’ of fluvial flooding, with less than a 1 in 1000 annual probability of river flooding in any year (<0.1%).

The Natural Resources Wales Surface Water flood map shows that the site has a very low risk of surface water flooding (see Figure 4) with a chance of surface water flooding of less than 1 in 1000 (0.1%) years. The surface water flood map represents the fluvial flood risk posed by the small watercourse accurately and confirms that the site would not be inundated with floodwater for all events up to and including the 1 in 1000 year event.

When climate change allowances are taken in account it is not expected to increase the 1 in 1000 year flood extent beyond the current 1 in 1000 year extent by 2118 extent, so the probability of fluvial flooding at the site is likely to remain greater than 1 in 1000 (0.1%) years, for the lifetime of the development. Therefore, the risk of fluvial flooding is considered to be **not significant**.

3.8 Tidal (coastal) Flooding

The site is not located within the vicinity of tidal flooding sources and therefore, the risk of fluvial flooding is considered to be **not significant**.

3.9 Groundwater Flooding

Groundwater flooding is defined as the emergence of groundwater at the ground surface or the rising of groundwater into man-made ground under conditions where the normal range of groundwater levels is exceeded.

Groundwater flooding tends to occur sporadically in both location and time. When groundwater flooding does occur, it tends to mostly affect low-lying areas, below surface infrastructure and buildings (for example, tunnels, basements and car parks) underlain by permeable rocks (aquifers).

Site conditions suggest a low probability of groundwater flooding. The local geology is not considered to yield significant volumes of groundwater. No below surface infrastructure and buildings are located or are proposed for the site. The risk of flooding from groundwater flooding is considered to be **not significant**.

3.10 Surface Water (pluvial) Flooding

The site is not situated near to large areas of poor permeability or areas with the geology and/or topography which may result in surface water flooding. The soil conditions at the site and within the vicinity of the site indicate that the site may be at risk of surface water flooding.

The Natural Resources Wales Surface Water flood map shows that the site has a very low risk of surface water flooding (see Figure 4) with a chance of surface water flooding of less than 1 in 1000 (0.1%) years. Surface flooding poses a very low flood risk to the site therefore, the risk of flooding from surface water flooding is considered to be **not significant**.

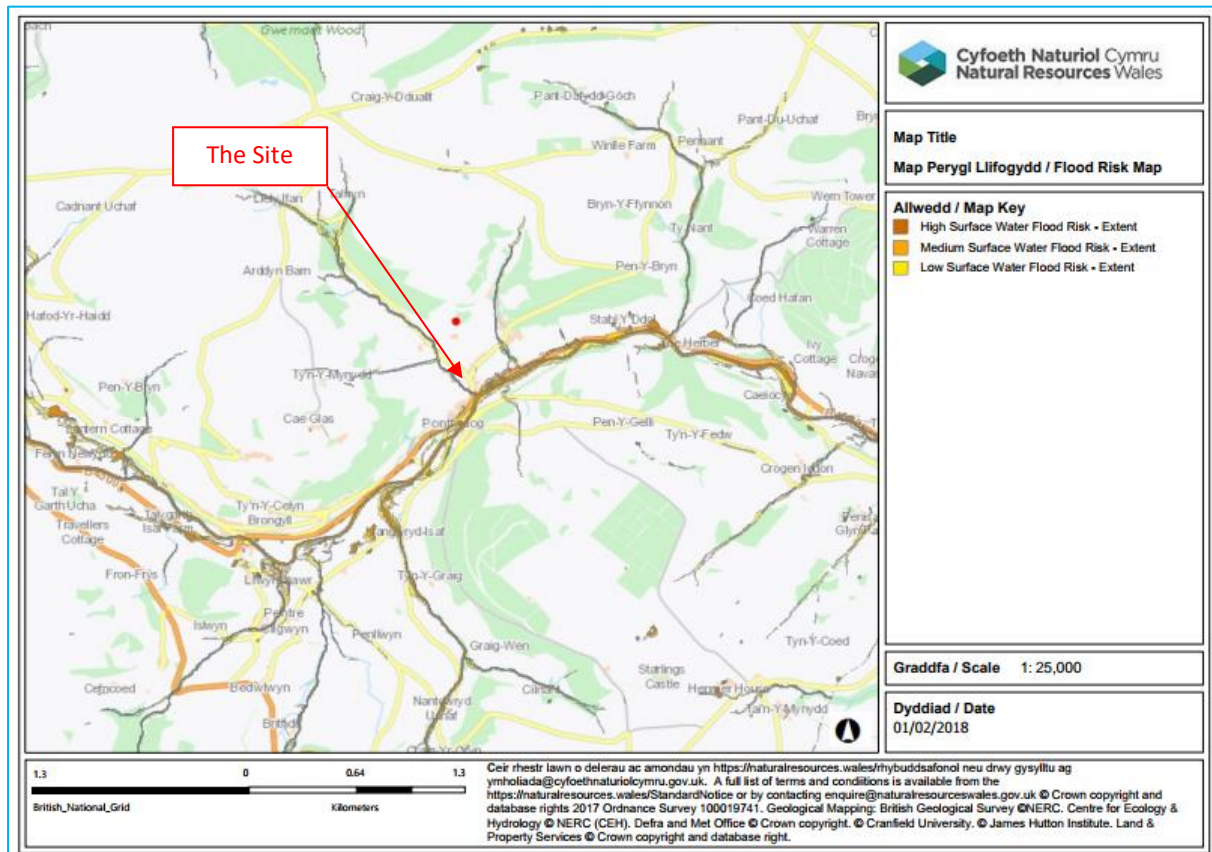


Figure 4 - Natural Resources Wales Surface Water Flood Map

3.11 Sewer Flooding

Sewer flooding occurs when urban drainage networks become overwhelmed and maximum capacity is reached. This can occur if there is a blockage in the network causing water to back up behind it or if the sheer volume of water draining into the system is too great to be handled. Sewer flooding tends to occur sporadically in both location and time such flood flows would tend to be confined to the streets around the development.

There are no public sewers located within the vicinity of the site. Flood flows could also be generated by burst water mains, but these would tend to be of a restricted and much lower volume than weather generated events and so can be discounted for the purposes of this assessment. Therefore, the risk of flooding from sewer flooding is considered to be **not significant**.

3.12 Flooding from Artificial Drainage Systems/Infrastructure Failure

There are no other nearby artificial water bodies, water channels and artificial drainage systems that could be considered a flood risk to the site. The Natural Resources Wales Reservoir flood map shows that the site is not at risk of reservoir flooding (see Figure 5). The risk of flooding from reservoir failure is considered to be **not significant**.

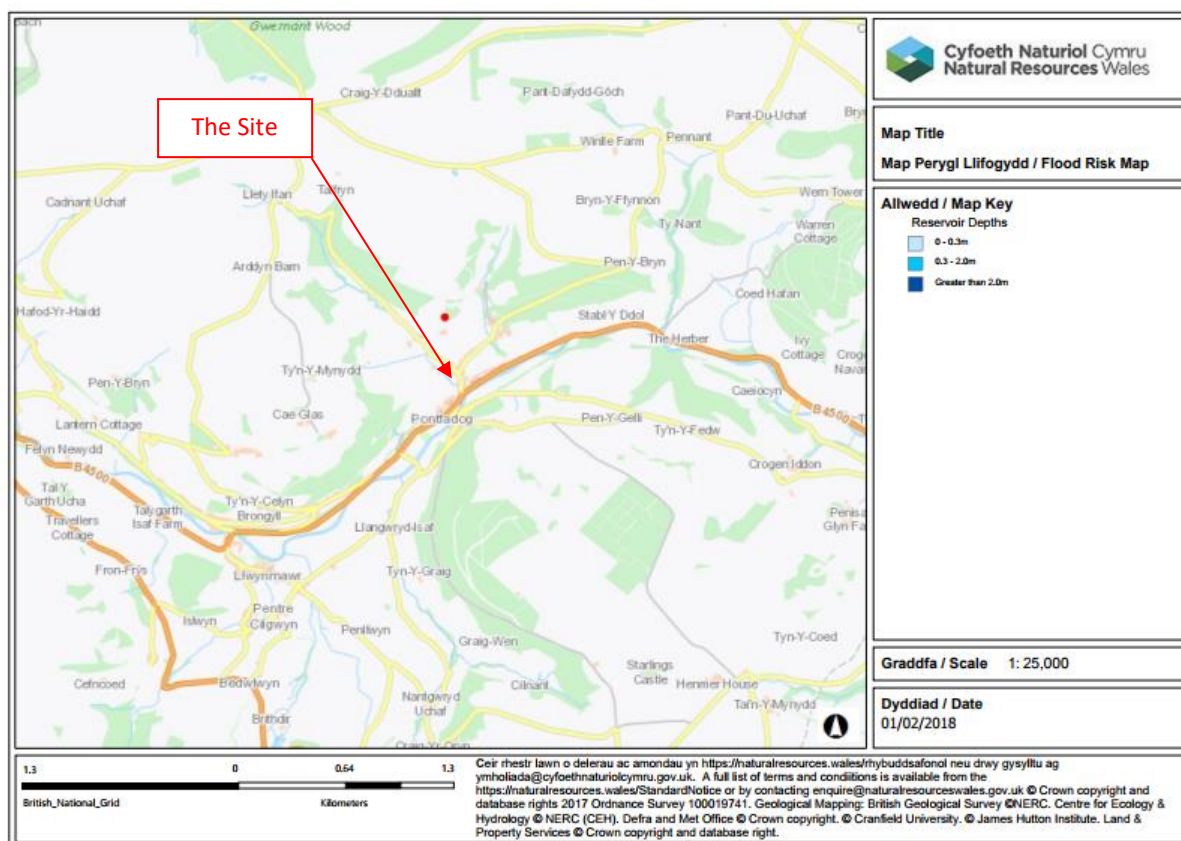


Figure 5 - Natural Resources Wales Reservoir Flood Map

3.13 Site Specific Flood Consequence Assessment

A summary of the sources of flooding and a review of the risk posed by each source at the site is shown in Table 4.

Table 4 - Risk Posed by Flooding Sources

Sources of Flooding	Potential Flood Risk	Potential Source	Probability/Significance
Fluvial Flooding	No	None Reported	None
Tidal Flooding	No	None Reported	None
Groundwater Flooding	No	None Reported	None
Surface Water Flooding	No	None Reported	None
Sewer Flooding	No	None Reported	None
Flooding from Artificial Drainage Systems/Infrastructure Failure	No	None Reported	None

The site is not at risk of flooding from a major source (e.g. fluvial and/or tidal). The site has not recent history of flooding. The site has a 'low probability' of fluvial/tidal flooding as the site is located within Flood Zone 1 with less than a 1 in 1000 annual probability of river or sea flooding in any year (<0.1%). When climate change allowances are taken in account it is not expected to increase the 1 in 1000 year flood extend beyond the current 1 in 1000 year extent by 2118 extent, so the probability of fluvial flooding at the site is likely to remain greater than 1 in 1000 (0.1%) years, for the lifetime of the development. Therefore, the risk of fluvial/tidal flooding is considered to be **not significant**.

Provided the buildings are set above the ground level to enable the full capacity of any secondary flood conveyance to be utilised, the risk of flooding from all sources is considered to be **not significant**.

There will be no net loss in flood storage capacity or impact on movement of floodwater across the site. The overall direction of the movement of water will be maintained within the developed site and surrounding area. The conveyance routes (flow paths) will not be blocked or obstructed.

The proposed use of the site is 'highly vulnerable', 'highly vulnerable' uses are appropriate within Flood Zone 1 and DAM Zone B after the completion of a satisfactory FCA. In conclusion, the flood risk to the site can be considered to be limited; the site is situated in Flood Zone 1 and DAM Zone B, with a very low annual probability of flooding and from all sources. The site is unlikely to flood except in very extreme conditions.

4.0 SURFACE WATER DRAINAGE

4.1 Surface Water Overview

It is recognised that consideration of flood issues should not be confined to the floodplain. The alteration of natural surface water flow patterns through developments can lead to problems elsewhere in the catchment, particularly flooding downstream. For example, replacing vegetated areas with roofs, roads and other paved areas can increase both the total and the peak flow of surface water runoff from the development site. Changes of land use on previously developed land can also have significant downstream impacts where the existing drainage system may not have sufficient capacity for the additional drainage.

A SUDS Strategy for the site proposals has been developed to manage and reduce the flood risk posed by the surface water runoff from the site. An assessment of the surface water runoff rates has been undertaken, in order to determine the surface water options and attenuation requirements for the site. The assessment considers the impact of the development compared to current conditions. Therefore, the surface water attenuation requirement for the developed site can be determined and reviewed against existing arrangements.

The requirement for managing surface water runoff from developments depends on the predeveloped nature of the site. If it is an undeveloped greenfield site, then the impact of the development will need to be mitigated so that the runoff from the site replicates the natural drainage characteristics of the pre-developed site. In the case of brownfield sites, drainage proposals will be measured against the existing performance of the site, although it is preferable for solutions to provide runoff characteristics that are similar to greenfield behaviour.

The surface water drainage arrangements for any development site should be such that the volumes and peak flow rates of surface water leaving a developed site are no greater than the rates prior to the proposed development, unless specific off-site arrangements are made and result in the same net effect.

It should be acknowledged that the satisfactory collection, control and discharge of surface water runoff are now a principle planning and design consideration. This is reflected in recently implemented guidance as well as the new Defra non-statutory technical standards for SUDS.

4.2 Climate change

Projections of future climate change, in the UK, indicate more frequent, short-duration, high intensity rainfall and more frequent periods of long duration rainfall. Guidance included within TAN15 recommends that the effects of climate change are incorporated into FCA's. The recommended national precautionary sensitivity range for peak rainfall intensity are summarised in (see Table 5).

Table 5 - Peak Rainfall Intensity Allowance in Small and Urban Catchment (use 1961 to 1990 baseline)

Parameter	2010 to 2039	2040 to 2059	2060 to 2115
Upper end	+ 10%	+ 20%	+ 40%
Central	+ 5%	+ 10%	+ 20%
Lower end	0%	+ 5%	+ 10%

4.3 Opportunities for Discharge of Surface Water

There are three possible options to discharge the surface water runoff in accordance with requirement H3 of the Building Regulations, this hierarchy is also promoted within TAN15. Rainwater shall discharge to one of the following, listed in order of priority:

- an adequate soakaway or some other adequate infiltration system; or, where that is not reasonably practicable,
- a watercourse; or where that is not reasonably practicable,
- a sewer.

It is necessary to identify the most appropriate method of controlling and discharging surface water.

4.4 Soakaway/Infiltration System

The general ground conditions suggest that the permeability and infiltration rate of the site will be low. SUDS methods such as soakaways may provide an adequate solution for the discharge of surface water runoff from the site. If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations. Such work is beyond the scope of this FCA but should be undertaken to inform the detailed drainage strategy for the site.

4.5 Watercourse

Should infiltration be found to be unsuitable, the next option is discharge to a watercourse. To the east of the site is a small watercourse. Discharge to the watercourse would be at existing greenfield runoff rates. By doing this, no additional pressure will be put onto the existing infrastructure and risk of flooding will not be increased. Therefore, it would be possible to discharge surface water runoff from the site into a watercourse.

4.6 Sewer

In the event that discharge of surface water via infiltration or discharge to a watercourse is deemed unsuitable, then discharge to the public sewer would be possible. All surface water runoff that cannot be discharged via infiltration or to a watercourse will be managed on site and then discharged to the public surface water sewer. Discharge to the sewers would be at a restricted runoff rate.

It would be prudent to undertake further detailed surveys to verify the inverts, depth and arrangement of the existing public sewer. Therefore, it will be possible to discharge to the public sewers.

4.7 Surface Water Runoff from the Existing Site

An estimation of surface water runoff is required to permit effective site water management and prevent any increase in flood risk to off-site receptors. In accordance with The SUDS Manual, the Greenfield runoff from the site has been calculated using the IoH124 method. Table 6 shows the IoH 124 method Greenfield run off rates calculated for the proposed impermeable area of 0.10 hectares (ha). QBAR has been calculated to be 0.33 litres/second (l/s).

The method used for calculating the runoff complies with TAN15, as well as the new Defra non-statutory technical standards for SUDS, and assumes that the excess runoff associated with the proposed development (plus an allowance for future climate change) will need to be managed by the proposed SUDS scheme.

Table 6 - IoH124 Method Greenfield Runoff Rates

Rainfall Event	Runoff Rate (l/s)
1	0.28
QBAR (rural)	0.33
30	0.57
100	0.71

4.8 SUDS and Water Quality

Current guidance promotes sustainable water management through the use of SUDS. SUDS measures should be used to control the surface water runoff from the proposed development site therefore, managing the flood risk to the site and surrounding areas from surface water runoff.

A hierarchy of techniques is identified²:

1. **Prevention** – the use of good site design and housekeeping measures on individual sites to prevent runoff and pollution (e.g. minimise areas of hard standing).
2. **Source Control** – control of runoff at or very near its source (such as the use of rainwater harvesting, permeable paving, soakaways and/or green roofs).
3. **Site Control** – management of water from several sub-catchments (including routing water from roofs and car parks to one/several large soakaways for the whole site, swales and/or infiltration trenches).
4. **Regional Control** – management of runoff from several sites, typically in a detention pond, basins, tanks and/or wetland.

It is generally accepted that the implementation of SUDS as opposed to conventional drainage systems, provides several benefits by:

- reducing peak flows to watercourses or sewers and potentially reducing the risk of flooding downstream;
- reducing the volumes and frequency of water flowing directly to watercourses or sewers from developed sites;
- improving water quality over conventional surface water sewers by removing pollutants from diffuse pollutant sources;
- reducing potable water demand through rainwater harvesting;
- improving amenity through the provision of public open spaces and wildlife habitat; and
- replicating natural drainage patterns, including the recharge of groundwater so that base flows are maintained.

² CIRIA (2004) Report C609, Sustainable Drainage Systems – Hydraulic, Structural and Water Quality advice.

The most appropriate attenuation system will need to satisfy three main characteristics, firstly, provide the required volume of storage, secondly, minimise the loss of developable land and thirdly, where possible provide local amenity.

The application of the SUDS Manual requires that the runoff from sites is not only restricted to meet the Greenfield runoff characteristics but also that SUDS systems are utilised to improve the quality of the runoff prior to outfall to watercourses. The SUDS Manual and Natural Resources Wales guidance applies a sustainability hierarchy to the various types of SUDS systems, this is summarised in Table 7.

Table 7 - Sustainability Hierarchy

Most Sustainable ↑ ↓ Least Sustainable	SUDS Technique	Flood Reduction	Pollution Reduction	Landscape & Wildlife
	Living Roofs	✓	✓	✓
	Basins and ponds - Constructed wetlands - Balancing ponds - Detention basins - Retention ponds	✓	✓	✓
	Filter strips and swales	✓	✓	✓
	Infiltration Devices - Soakaways	✓	✓	✓
	Permeable Surfaces and Filter Drains - Gravelled areas - Solid paving blocks - Permeable paving	✓	✓	
	Tanked systems - Over-sized pipes/tanks - Cellular storage	✓		

Systems at the top of the hierarchy provide a combination of attenuation, treatment and ecology and are deemed the most sustainable options. There are always specific scenarios where systems are more suitable than others and at this stage it is not possible to guide the development towards a particular strategy.

In addition to the above hierarchy the SUDS Manual identifies the number of treatment trains or SUDS devices through which flow should pass from various point sources of runoff (see Table 8). This is designed to ensure that the receiving environments are not put at risk of pollution by new development therefore; accordingly, one treatment train will be used on this site.

The usual approach is to consider the 'SUDS train' where each of the above options are considered in turn until a suitable solution is found. Thus, source control techniques such as soakaways, rainwater harvesting and/or infiltration trenches, if suitable on a site, are considered preferable to permeable conveyance and passive treatment systems such as tanks or ponds. The various options are considered in outline below.

Table 8 - Number of Treatment Train Components (assuming effective pre-treatment is in place)

Runoff Catchment Characteristic	Receiving Watercourse Sensitivity		
	Low	Medium	High
Roof only	1	1	1
Residential roads Parking areas Commercial zones	2	2	3
Refuse collection Industrial areas Loading bays Lorry parks Highways	3	3	4

4.9 Source Control

(i) Soakaways

Soakaways are buried rings or tanks filled with rubble or stone and allow gradual infiltration of collected runoff from impermeable areas into the surrounding soil. They require relatively permeable strata below a site to allow percolation and the reduction in runoff is achieved by the volume of percolation and the available storage volume. An assessment of their suitability requires the characteristics of the sub-soils or the geology to confirm the infiltration rate or vertical permeability.

There is no specific amenity provided by the system other than enabling other areas to be utilised for development rather than potentially sterilizing areas with an easement for a sewer or stand-off for a basin. It has been concluded that soakaways may not provide an adequate solution for the discharge of surface water runoff from the site.

(ii) Permeable Paving

The use of permeable paving can often be considered for pedestrian or car parking areas but not for heavy traffic areas such as roadways where the heavy loading could damage the paving infrastructure. Permeable paving also depends on having permeable underlying strata. The permeable paving can either discharge via infiltration or discharge to cellular storage.

Permeable paving will provide storage for the first 5mm (interception storage) as a minimum. It should be noted that any permeable paving system to be installed by a developer must have an infiltration rate of at least 30mm/hr (0.03m/hr) to avoid ponding on the surface before it reaches the natural soil (permeable paving systems generally would have an infiltration rate in excess of 30mm/hr).

These systems also encourage biological treatment of flow and extraction of oils and heavy metals from the run-off. Treatment processes that occur within the surface structure and the geotextile layers include:

- Filtration
- Absorption
- Biodegradation
- Sedimentation

Land take is reduced as storage is located under car parks and access roads. However, maintenance is potentially a long-term issue and the possibility of the paving being damaged, dug up and not

properly reinstated or not regularly swept could lead to compromising the future capacity of the system.

This system will negate the need for a separate collection system such as kerbs and gullies. It will also assist in reducing the flood profile of the site by significantly attenuating the run-off from the development within the sub base material.

There is no specific amenity provided by the system other than enabling other areas to be utilised for development rather than potentially sterilizing areas with an easement for a sewer or stand-off for a basin.

It is most likely that permeable paving will be utilised within the driveways of the dwellings and car parking spaces. Provided that this is laid onto a thick open-graded sub-base, this provide sufficient storage for the runoff before discharge via infiltration or to cellular storage such that the 1 in 100 year (+40%) event can be fully discharged.

(iii) Rainwater Harvesting

The reuse of water from roofed areas to provide grey (non-potable) water for flushing WCs within buildings can reduce storm runoff without the need for treatment or oil separators since the risk of spillage or contamination is low. Such a facility could be practical depending on the available water volumes. Over the course of a year a grey water system will reduce the volume of water entering the storm water disposal system and could be considered.

Such a system would require one or more tanks at roof level and under optimum conditions these would be kept as near as full as possible to ensure a reliable water supply. For the purposes of a worst-case design scenario it is assumed that the tanks would be full at the start of an extreme rainfall event and hence all storm rainfall would enter the surface water drainage system rather than grey water storage. Whilst there may be merit in including such a scheme in the overall designs these are not considered appropriate in the SUDS assessment.

(iv) Green Roofs

A green roof is a multi-layered system that covers the top of a building with soil and vegetation and which can provide a degree of rain storm attenuation and a reduction in site runoff. These can either be extensive roofs which are low maintenance with a 25-125mm soil layer in which a variety of hardy drought tolerant low plants are grown, or intensive roofs with trees and planters which impose a greater load on the roof structure but are more suitable in certain circumstances. Green roofs can be used to reduce the volume and rate of runoff so that other SUDS techniques in the scheme can be significantly reduced in size. However, the dwellings will not have flat roofs therefore, green roofs would not be appropriate for this site.

(v) Water Butts

Water butts are the most common means of harvesting rainwater for garden use. They are small, offline storage devices that are designed to capture and store roof runoff. They are a simple water conservation technique that can contribute to sustainable water management for developed areas. In general water butts, do not provide water quality treatment. A water butt collects rainwater from roofs via an inlet that is connected to the roof down-pipe. Water butts are manufactured in a wide variety of sizes and can consist of inter-connectable units.

During wet periods, water butts are often full, resulting in little or no attenuation or reduction in outflow rates or volumes. However, water butts can be designed to attenuate runoff by using a throttled overflow system with excess water discharge to the drainage system or soakaway.

Water butts could be used to provide betterment but not as the primary system and have therefore not been included within any storage volume calculations.

4.10 Site Control - Permeable Conveyance Systems

Permeable conveyance systems can take the form of infiltration trenches, swales or filter strips at road margins where surface runoff from roads, car parking areas and also roof drainage can be directed. Used to collect water directly from linear systems, percolate the flow, attenuate and then discharge the flow to either a traditional system or a secondary SUDS device.

The use of these systems is more suited to linear applications such as roads as the typical cross section is relatively small and longer runs are required to provide attenuation volume. Land take can be relatively small in comparison to other systems and both types perform well in improving water quality. They are also ideally suited for disposal of water via secondary infiltration.

It is likely that these features could be utilised as the first treatment train and as part of the site collection and conveyance system.

(i) Infiltration Trench

Infiltration trenches are essentially linear soakaways which allows water to infiltrate into the soils as it is transported to a disposal point. There is space available on this site to provide a length of infiltration trench.

(ii) Swales

Swales are open wide trapezoidal channels across a site which allows water to infiltrate into the soils as it is transported to a disposal point. There is space available on this site to provide a length of swale.

(iii) Filter Strips

Filter strips will be smaller in plan area than a swale. There is space available on this site to provide a length of filter strip and it is likely that these will provide a suitable means of surface water disposal.

4.11 Passive Treatment Systems

Where ground conditions prevent the use of infiltration, such as on ground that may be impermeable or contaminated, SUDS methods that are designed not to infiltrate can be considered. Passive treatment systems can include a pond, wetland, tank or a basin on the lower parts of a site. These will reduce peak flows, but not the volume of runoff, and slow down flows before disposal to a surface water drainage system. These may provide a suitable SUDS solution for this site and options are therefore considered in outline below.

(i) Ponds and Basins

The nature of these systems is such that the runoff from the development can be treated by biological action and stilling to significantly improve the quality of water discharged from the system.

Basins also provide large areas of open space that can be developed for recreational uses or as new habitats for wildlife. Both systems do, however, take up significant amounts of developable land and have residual maintenance and liability issues attached to their implementation. Due to the small size of the site this option is not practical for the site.

(ii) Underground Storage Tanks

Hard engineered tank storage systems have traditionally been used for attenuation structures for the past decade and are often specified where large volumes of storage are required (>200m³) and available space is an issue. These could be located underneath the roads and paved areas.

These systems have no inherent water treatment properties bar potential sedimentation of the attenuated flow and offer no additional amenity benefits. In some cases, the easement to the tank or culvert is such that a significant portion of land area is sterilized from development and certain planting.

There are also significant costs associated with these systems in production, transportation and installation. However, once installed the long-term maintenance of the system is relatively low. With a proven record of successful installation, tanks and culverts are regularly adopted by water authorities across the country, albeit with a large associated easement that will sterilise that portion of the site. The site layout allows for storage tanks under the highways located on the site.

(iii) Oversized Drainage Network

A further option on storage and attenuation would be the use of an oversized drainage network designed to act as inline storage, rather than a tank or pond, to provide the required storage volume underground. These could be located underneath the roads and paved areas.

As the diameter of larger pipes readily available is limited the applicability of these types of systems is more suited to <200m³ of attenuation. Above this volume, the length of pipe required is excessive and difficult to suitably fit into a normal site layout. There is no intrinsic amenity provided by the use of this system neither is there any specific level of run-off treatment over and above that of a standard pipe and gully system.

However, due to their traditional nature, the adoption of these types of systems by water authorities is straightforward and does not require any specialist input. The pipes are generally available direct from suppliers with little or no lead in time and the satisfactory long-term performance of these systems is well documented.

It has been concluded that oversized drainage networks will work at the site and can be used to attenuate the surface water runoff. The site layout allows for an oversized drainage network under the highways located on the site.

(iv) Cellular Storage

Large volumes of storage can be provided under grassed and lightly trafficked areas by using proprietary plastic cellular systems. This will maximise the developable area of the site. These could be located underneath the roads and paved areas.

There is no specific mechanism within the system designed to treat flow, but extended detention times will allow sedimentation reducing the suspended solids within the discharge. There is no creation of amenity by the installation of these types of systems, indeed by maintaining access to the system small areas may need to be reserved.

If the developable footprint is tight then these systems may be advantageous however to ensure adoptability it is recommended that the use of these systems is discussed with the adopting authority as they are not always preferred.

There would be room to install cellular storage under the drive way areas to provide the storage volume required. This will require the new drainage network to divert flow from the impermeable

buildings and parking areas to this cellular storage facility. This could also be drained via permeable pavement surfaces.

It has been concluded that cellular storage will work at the site and can be used to attenuate the surface water runoff. The site layout allows for cellular storage under the highways located on the site.

(v) Surface Storage

The use of roads, public areas and even landscaped areas as additional storage is becoming a widely accepted form of attenuation. Water spilling from drainage systems can be collected via roads and kerbs and channelled to lower lying areas where it would be stored until the capacity in the existing system returns. These systems have the advantage of requiring little additional infrastructure merely detailing of the proposed roads and grassed areas.

As these systems, will only be used in extreme events when the adopted drainage system is exceeded (>1 in 30 years), they provide a very efficient way of catering for these events rather than providing permanent capacity.

There is no inherent water treatment capability in this system or any particular increase in amenity; however, the costs associated with this provision are relatively small. It is recommended that these systems are only used in emergency circumstances (e.g. for events greater than the 1 in 30 year event).

4.12 Site Storage Volumes

The provision of suitable storage on site to mitigate the flood risk resulting from the development of the site will be a key factor in the evolution of the site development layout. The provision of large volumes of attenuation, as is likely in this case, can be achieved by a number of methods; however, not all systems can be assessed in direct comparison.

One of the aims of TAN15 is to provide not only flood risk mitigation but also to maximise additional gains such as improvements in runoff quality and provision of amenity and bio-diversity. Systems incorporating these features are often termed SUDS and it is the requirement TAN15 that these are considered as the primary means of collection, control and disposal for storm water as close to source as possible.

The principle applied in the design of storage is to limit the discharge rate of surface water runoff from the developed site for events of similar frequency of occurrence to the same peak rate of runoff as that which takes place from a greenfield site prior to development.

4.13 Site Storage Volumes – Assuming Infiltration

At this stage, ground conditions suggest that infiltration methods such as soakaways and permeable paving will work at the site. The soakaways would be sized according to on site infiltration rates obtained during infiltration/soakaway tests. If the soakaways are sized for example the 1 in 10 year event an overflow would discharge water to another SUDS feature (e.g. permeable paving) during events larger than the 1 in 10 year event.

Tables 9 shows The BRE365 calculation procedure for a trench soakaway with a void ratio of 30% within the Masterdrain Drainage Software was used to demonstrate that the proposed surface water runoff volumes can be viably accommodated on site and drained by infiltration during the 10, 30, and 100 year storms with a 40% allowance for climate change assuming an impermeable area 0.10ha (see Appendix 1). The required half emptying time of 24 hours for each of the design storms is met and therefore this method of storm water disposal is appropriate for use on this site. This is based on an

infiltration rate of 0.00003m/s. Additional storage would be provided within the manholes, pipes and drainage gullies which will provide betterment over and above the 1 in 100 year (+40%) event.

If an infiltration system is proposed, it is recommended that a series of infiltration/soakaway tests are carried out on site to BRE Digest 365 Guidelines to confirm the assumptions made in the calculations.

Table 9 - BRE365 Trench Soakaway Calculations

Return Period (years)	Impermeable Area (m ²)	Length (m)	Width (m)	Depth (m)	Required Volume (m ³)	Actual Volume (m ³)	Half Emptying Time (hr:min)
10 +40%	1,000	15	6.50	2.00	28.00	58.50	03:00
30 +40%					39.30	58.50	04:13
100 +40%					57.20	58.50	06:09

4.14 Site Storage Volumes assuming No Infiltration

Where ground conditions prevent the use of infiltration, such as on ground that may be impermeable or contaminated, SUDS methods that are designed not to infiltrate can be considered. QBAR (rural) has been calculated to be 0.33l/s. It is not practical to restrict surface water runoff to below 5.00l/s (due to the increase risk of blockage) therefore, discharge from the site will be limited to 5.00l/s for all events up to and including the 1 in 100 year (+40%) event.

Table 10 shows the volume of storage required for the proposed development estimated within the Masterdrain Drainage Software for the 1 in 100 year event, with a 40% allowance for climate change (increase in peak rainfall) assuming the proposed 0.10ha of impermeable area with 5.00l/s used as the limiting discharge rate before discharge to the small watercourse (see Appendix 2).

At this stage, it is proposed that underground storage tanks, oversized drainage networks, cellular storage and/or surface storage will be used to provide the require attenuation storage volume of 35.50m³. Additional storage would be provided within the manholes, pipes and drainage gullies which will provide betterment over and above the 1 in 100 year (+40%) event.

Table 10 - Attenuation Storage Calculations

Return Period (years)	Limiting Discharge Rate (l/s)	Volume (m ³)
2 +40%	5.00	9.80
30 +40%		24.20
100 +40%		35.50

4.15 Proposed SUDS Strategy

The objective of this SUDS Strategy is to ensure that a sustainable drainage solution can be achieved which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the site. At this stage, a detailed surface water drainage design has not been undertaken, however it is necessary to demonstrate that the surface water from the proposed development can be discharged safely and sustainably. The SUDS Strategy takes into account the following principles:

- No increase in the volume or runoff rate of surface water runoff from the site.
- No increase in flooding to people or property off-site as a result of the development.

- No surface water flooding of the site.
- The proposals take into account a 20% increase in rainfall intensity due to climate change during the next 100 years which is the lifetime of the development.

In line with adopting a 'management train' it is recommended that water is managed as close to source as possible. This will reduce the size and cost of infrastructure further downstream and also shares the maintenance burden more equitably. The Outline SUDS Strategy will take the form of:

- Water Butts.
- Soakaways.
- Permeable paving of driveways/car parking areas.
- Permeable conveyance features - infiltration trenches, swales, filter strips.
- If required, oversized pipes/cellular storage/storage tanks with a restricted runoff rate to the small watercourse.
- For larger events in other areas such as car parking and landscaping, provided that it will not cause damage or prevent access.

For all development, both the Building Regulations and TAN15 promote a hierarchical approach to surface water management. This approach has been adopted within this SUDS Strategy with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the small watercourse at a restricted runoff rate of 5.00l/s.

The size of the storage has been calculated such that the proposed development has the capacity to accommodate the 1 in 100 year rainfall event including a 40% increase in rainfall intensity that is predicted to occur as a result of climate change. Consequently, all areas drained have been designed to accommodate a 100 year (+40% climate change) storm event. The remainder of the site that is not formally drained, i.e. landscaped areas, will be permeable (grass). The majority of rainwater falling on these areas will soak into the ground. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas. Additional storage would be provided within the manholes, pipes and drainage gullies which will provide betterment over and above the 1 in 100 year (+40%) event.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for this site. The adoption of a SUDS Strategy for the site represents an enhancement from the current conditions as the current surface water runoff from the site is uncontrolled, untreated, unmanaged and unmitigated. The SUDS Strategy will reduce the risk of flooding to the site and off-site locations.

In adopting these principles, it has been demonstrated that a scheme can be developed that does not increase the risk of flooding to adjacent properties and development further downstream.

4.16 Designing for Local Drainage System Failure

When considering residual risk, it is necessary to make predictions as to the impacts of a storm event that exceeds the design event, or the impact of a failure of the local drainage system. The SUDS

Strategy applies a safe and sustainable approach to discharging rainfall runoff from the site and this reduces the risk of flooding however, it is not possible to completely remove the risk. This section of the FCA is therefore associated with the way the residual risk is managed.

As part of the SUDS Strategy it must be demonstrated that the flooding of property would not occur in the event of local drainage system failure and/or design exceedance. It is not economically viable or sustainable to build a drainage system that can accommodate the most extreme events. Consequently, the capacity of the drainage system may be exceeded on rare occasions, with excess water flowing above ground.

The size of the storage has been designed to accommodate the 1 in 100 year storm event plus climate change (+40%). The design of the site layout provides an opportunity to manage this local drainage system failure/exceedance flow and ensure that indiscriminate flooding of property does not occur.

There will not be an extensive sewerage network on the proposed development site and therefore any potential exceedance flooding would be from the sewers and lateral drains connecting the buildings to the underground storage areas. It is very unlikely that a catastrophic failure would occur. An exceedance or blockage event of the sewers would not affect the proposed buildings because the finished floor level will be raised above surrounding ground levels, ensuring any exceedance flooding would not affect the buildings. Exceedance flows would be contained within the highways adjacent to the site and within the site and would flow to the lower ground levels where the public open space is located. It is not considered that there is an increased risk to the properties on the site or located adjacent to the site.

In particular, the landscaped areas will include preferential flow paths that convey water away from buildings. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas.

When considering the impacts of a storm event that exceeds the 1 in 100 year (+40%) event, there is safety factor, even under the design event conditions. Consequently, if this event were to be exceeded there is additional capacity with the system to accommodate this (i.e. within the manholes, pipes etc.). If this freeboard was to be exceeded the consequences would be similar, if not less than for the local drainage system failure. Consequently, the impact of an exceedance event is not considered to represent any significant flood hazard.

The above manages and mitigates the flood risk from surface water runoff to the proposed properties from surface water runoff generated by the site development and to offsite locations as well the risk from surface water runoff generated offsite.

5.0 RISK MANAGEMENT

5.1 Introduction

In this flood zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development and the use of flood mitigation measures.

A number of techniques and mitigation strategies to manage and reduce the overall flood risk in the area will be used. This will ensure the development will be safe and there is:

- Minimal risk to life;
- Minimal disruption to people living and working in the area;
- Minimal potential damage to property;
- Minimal impact of the proposed development on flood risk generally; and;
- Minimal disruption to natural heritage.

The flood risk at the site will be reduced by using a number of risk management measures to manage and reduce the overall flood risk at the site.

5.2 Minimum Floor Level

There is no minimum finished floor level proposed as a result of flooding. However, it is recommended that all buildings are located above the back of footway of the adjacent highway to enable the full capacity of any secondary flood conveyance to be utilised.

5.3 Flood Resilience and Resistance

The development of the layout should always consider that the site is potentially at risk from an extreme event and as such the implementation of flood resilience and resistance methods should be assessed.

To make the buildings more resistant to seepage the following measures will be incorporated. Sealant will be used around external doors and windows. All windows will be located above the ground levels. All external doors and windows will be constructed from synthetic materials.

To improve the buildings resilience to flooding the following measures will be incorporated. All electrical wiring, switches, sockets, socket outlets, electrical, and gas meters etc. will be located a minimum of 450mm above the finished floor level.

5.4 Safe Access and Egress

The site and surrounding area is located within Flood Zone 1 therefore a permanently safe and dry access can be maintained.

5.5 Buffer Strip

A buffer strip adjacent to the top of the watercourse will be retained for maintenance purposes. This will be free of built development.

5.6 Flooding Consequences

The mitigation measures detailed above show that the flood risk can be effectively managed and therefore the consequences of flooding are acceptable. In conclusion, the flood risk to the site can be considered to be limited; the site is situated in Flood Zone 1, with a very low annual probability of flooding and from all sources.

6.0 JUSTIFYING THE LOCATION OF THE DEVELOPMENT

6.1 Justification Test

New development should be directed away from Zone C and towards suitable land in Zone A, otherwise to Zone B, where river or coastal flooding will be less of an issue. The site is not at risk of flooding from a major source (e.g. fluvial and/or tidal). The site has not recent history of flooding. The site has a 'low probability' of fluvial/tidal flooding as the site is located within Flood Zone 1 with less than a 1 in 1000 annual probability of river or sea flooding in any year (<0.1%). When climate change allowances are taken in account it is not expected to increase the 1 in 1000 year flood extent beyond the current 1 in 1000 year extent by 2118 extent, so the probability of fluvial flooding at the site is likely to remain greater than 1 in 1000 (0.1%) years, for the lifetime of the development. Therefore, the risk of fluvial/tidal flooding is considered to be **not significant**.

Provided the buildings are set above the ground level to enable the full capacity of any secondary flood conveyance to be utilised, the risk of flooding from all sources is considered to be **not significant**.

There will be no net loss in flood storage capacity or impact on movement of floodwater across the site. The overall direction of the movement of water will be maintained within the developed site and surrounding area. The conveyance routes (flow paths) will not be blocked or obstructed.

The proposed use of the site is 'highly vulnerable', 'highly vulnerable' uses are appropriate within Flood Zone 1 and DAM Zone B after the completion of a satisfactory FCA. In conclusion, the flood risk to the site can be considered to be limited; the site is situated in Flood Zone 1 and DAM Zone B, with a very low annual probability of flooding and from all sources. The site is unlikely to flood except in very extreme conditions.

The development proposals should therefore be considered to satisfy Justification Test as set out in TAN15.

7.0 SUMMARY AND CONCLUSIONS

7.1 Introduction

This report presents a FCA in accordance with TAN15 for the proposed development on Land behind Sion Chapel, Pontfadog, LL20 7AS.

This FCA identifies and assesses the risks of all forms of flooding to and from the development and demonstrates how these flood risks will be managed so that the development remains safe throughout the lifetime, taking climate change into account.

7.2 Flood Risk

The site is not at risk of flooding from a major source (e.g. fluvial and/or tidal). The site has not recent history of flooding. The site has a 'low probability' of fluvial/tidal flooding as the site is located within Flood Zone 1 with less than a 1 in 1000 annual probability of river or sea flooding in any year (<0.1%). When climate change allowances are taken in account it is not expected to increase the 1 in 1000 year flood extend beyond the current 1 in 1000 year extent by 2118 extent, so the probability of fluvial flooding at the site is likely to remain greater than 1 in 1000 (0.1%) years, for the lifetime of the development. Therefore, the risk of fluvial/tidal flooding is considered to be **not significant**.

Provided the buildings are set above the ground level to enable the full capacity of any secondary flood conveyance to be utilised, the risk of flooding from all sources is considered to be **not significant**.

There will be no net loss in flood storage capacity or impact on movement of floodwater across the site. The overall direction of the movement of water will be maintained within the developed site and surrounding area. The conveyance routes (flow paths) will not be blocked or obstructed.

The proposed use of the site is 'highly vulnerable', 'highly vulnerable' uses are appropriate within Flood Zone 1 and DAM Zone B after the completion of a satisfactory FCA. In conclusion, the flood risk to the site can be considered to be limited; the site is situated in Flood Zone 1 and DAM Zone B, with a very low annual probability of flooding and from all sources. The site is unlikely to flood except in very extreme conditions.

7.3 SUDS Strategy

The SUDS Strategy ensures that a sustainable drainage solution can be achieved which reduces the peak discharge rate to manage and reduce the flood risk posed by the surface water runoff from the site. At this stage, a detailed surface water drainage design has not been undertaken, however it is necessary to demonstrate that the surface water from the proposed development can be discharged safely and sustainably. The SUDS Strategy takes into account the following principles:

- No increase in the volume or runoff rate of surface water runoff from the site.
- No increase in flooding to people or property off-site as a result of the development.
- No surface water flooding of the site.
- The proposals take into account a 20% increase in rainfall intensity due to climate change during the next 100 years which is the lifetime of the development.

In line with adopting a 'management train' it is recommended that water is managed as close to source as possible. This will reduce the size and cost of infrastructure further downstream and also shares the maintenance burden more equitably. The Outline SUDS Strategy will take the form of:

- Water Butts.
- Soakaways.
- Permeable paving of driveways/car parking areas.
- Permeable conveyance features - infiltration trenches, swales, filter strips.
- If required, oversized pipes/cellular storage/storage tanks with a restricted runoff rate to the small watercourse.
- For larger events in other areas such as car parking and landscaping, provided that it will not cause damage or prevent access.

For all development, both the Building Regulations and TAN15 promote a hierarchical approach to surface water management. This approach has been adopted within this SUDS Strategy with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the small watercourse at a restricted runoff rate of 5.00l/s.

The size of the storage has been calculated such that the proposed development has the capacity to accommodate the 1 in 100 year rainfall event including a 40% increase in rainfall intensity that is predicted to occur as a result of climate change. Consequently, all areas drained have been designed to accommodate a 100 year (+40% climate change) storm event. The remainder of the site that is not formally drained, i.e. landscaped areas, will be permeable (grass). The majority of rainwater falling on these areas will soak into the ground. Surface water runoff would be directed to the drainage system through drainage gullies located around the perimeter of the buildings and through contouring of the hardstanding areas. Additional storage would be provided within the manholes, pipes and drainage gullies which will provide betterment over and above the 1 in 100 year (+40%) event.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for this site. The adoption of a SUDS Strategy for the site represents an enhancement from the current conditions as the current surface water runoff from the site is uncontrolled, untreated, unmanaged and unmitigated. The SUDS Strategy will reduce the risk of flooding to the site and off-site locations.

In adopting these principles, it has been demonstrated that a scheme can be developed that does not increase the risk of flooding to adjacent properties and development further downstream.

7.4 Risk Management

The flood risk at the site will be reduced by using a number of risk management measures to manage and reduce the overall flood risk at the site. Measures used:

Minimum Floor Level: There is no minimum finished floor level proposed as a result of flooding. However, it is recommended that all buildings are located above the back of footway of the adjacent highway to enable the full capacity of any secondary flood conveyance to be utilised.

Flood Resilience and Resistance: To make the buildings more resistant to seepage the following measures will be incorporated. Sealant will be used around external doors and windows. All windows will be located above the ground levels. All external doors and windows will be constructed from synthetic materials.

To improve the buildings resilience to flooding the following measures will be incorporated. All electrical wiring, switches, sockets, socket outlets, electrical, and gas meters etc. will be located a minimum of 450mm above the finished floor level.

Safe Access and Egress: The site and surrounding area is located within Flood Zone 1 therefore a permanently safe and dry access can be maintained.

Buffer Strip: A buffer strip adjacent to the top of the watercourse will be retained for maintenance purposes. This will be free of built development.

7.5 Justification Test

The development proposals should be considered to satisfy the Justification Test as set out in TAN15.

7.6 Conclusion

In conclusion, a residential development, would be expected to remain dry in all but the most extreme conditions. Providing the recommendations made in this FCA are instigated, flood risk from all sources would be minimised, the consequences of flooding are acceptable, and the development would be in accordance with the requirements of TAN15.

This FCA demonstrates that the proposed development would be operated with minimal risk from flooding, would not increase flood risk elsewhere and is compliant with the requirements of TAN15. The development should not therefore be precluded on the grounds of flood risk.

APPENDICES

APPENDIX 1 – Storage Calculations: Assuming Infiltration



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 100 Year (+40%) Soakaway Calculations**

Rectangular pit design data:-

Pit length	= 15 m	Pit width	= 6.5 m
Depth below invert	= 2 m	Percentage voids	= 30.0%
Imperm. area	= 1000 m ²	Infilt. factor	= 0.00003 m/s
Return period	= 100 yrs	Climate change	= 40%

Calculations :-

Surface area of soakaway to 50% storage depth (not inc. base):-

$$a_{s50} = 2 \times (\text{length} + \text{width}) \times \text{depth}/2 = 43.0 \text{ m}^2$$

Outflow factor : $O = a_{s50} \times \text{Infiltration rate} = 0.00129 \text{ m/s}$

Soakaway storage volume : $S_{\text{actual}} = \text{length} \times \text{width} \times \text{depth} \times \% \text{voids}/100 = 58.5 \text{ m}^3$

Duration	Rainfall mm/hr	Inflow m ³	Depth (hmax) m	Outflow m ³	Storage m ³
5 mins	193.0	16.0	0.53	0.39	15.64
10 mins	145.4	24.1	0.80	0.77	23.36
15 mins	118.6	29.7	0.97	1.16	28.49
30 mins	79.4	39.7	1.28	2.32	37.38
1 hrs	50.8	50.8	1.58	4.64	46.17
2 hrs	31.5	62.9	1.83	9.29	53.65
4 hrs	18.9	75.8	1.95	18.58	57.18
6 hrs	13.9	83.3	1.90	27.86	55.43
10 hrs	9.4	93.9	1.62	46.44	47.45
24 hrs	4.8	114.3	0.10	111.46	2.88

Actual volume : $S_{\text{actual}} = 58.500 \text{ m}^3$

Required volume : $S_{\text{reqd.}} = 57.180 \text{ m}^3$

Soakaway volume storage OK.

Minimum required a_{s50} : 42.03 m²

Actual a_{s50} : 43.00 m²

Minimum depth required: 1.95 m

Time to maximum 4 hrs

Emptying time to 50% volume = $t_{s50} = S_{\text{reqd}} \times 0.5 / (a_{s50} \times \text{Infiltration rate}) = 06:09 \text{ (hr:min)}$

Soakaway emptying time is OK.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 100 Year (+40%) Soakaway Calculations**

Location hydrological data (FSR):-

Location	=	GLYN CEIRIOG	Grid reference	=	SJ2038
M5-60 (mm)	=	18	r	=	0.36
Soil index	=	0.30	SAAR (mm/yr)	=	1150
WRAP	=	2	Area	=	England and Wales

Soil classification for WRAP type 2

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils;
- iii) Moderately permeable soils, some with slowly permeable subsoils.

N.B. The rainfall rates are calculated using the location specific values above in accordance with the Wallingford procedure.



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Date **02/02/18**

Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Soakaway Calculations**

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Rectangular pit design data:-

Pit length	= 15 m	Pit width	= 6.5 m
Depth below invert	= 2 m	Percentage voids	= 30.0%
Imperm. area	= 1000 m ²	Infilt. factor	= 0.00003 m/s
Return period	= 30 yrs	Climate change	= 40%

Calculations :-

Surface area of soakaway to 50% storage depth (not inc. base):-

$$a_{s50} = 2 \times (\text{length} + \text{width}) \times \text{depth}/2 = 43.0 \text{ m}^2$$

Outflow factor : $O = a_{s50} \times \text{Infiltration rate} = 0.00129 \text{ m/s}$

Soakaway storage volume : $S_{\text{actual}} = \text{length} \times \text{width} \times \text{depth} \times \% \text{voids}/100 = 58.5 \text{ m}^3$

Duration	Rainfall mm/hr	Inflow m ³	Depth (hmax) m	Outflow m ³	Storage m ³
5 mins	153.2	12.7	0.42	0.39	12.33
10 mins	113.6	18.9	0.62	0.77	18.08
15 mins	91.9	23.0	0.75	1.16	21.81
30 mins	60.9	30.5	0.96	2.32	28.13
1 hrs	38.7	38.7	1.16	4.64	34.07
2 hrs	23.9	47.8	1.32	9.29	38.56
4 hrs	14.5	57.9	1.34	18.58	39.28
6 hrs	10.7	64.0	1.24	27.86	36.18
10 hrs	7.3	72.7	0.90	46.44	26.30
24 hrs	3.7	90.0	0.00	111.46	0.00

Actual volume : $S_{\text{actual}} = 58.500 \text{ m}^3$

Required volume : $S_{\text{reqd.}} = 39.280 \text{ m}^3$

Soakaway volume storage OK.

Minimum required a_{s50} : 28.87 m²

Actual a_{s50} : 43.00 m²

Minimum depth required: 1.34 m

Time to maximum 4 hrs

Emptying time to 50% volume = $t_{s50} = S_{\text{reqd}} \times 0.5 / (a_{s50} \times \text{Infiltration rate}) = 04:13 \text{ (hr:min)}$

Soakaway emptying time is OK.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Soakaway Calculations**

Location hydrological data (FSR):-

Location	= GLYN CEIRIOG	Grid reference	= SJ2038
M5-60 (mm)	= 18	r	= 0.36
Soil index	= 0.30	SAAR (mm/yr)	= 1150
WRAP	= 2	Area	= England and Wales

Soil classification for WRAP type 2

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils;
- iii) Moderately permeable soils, some with slowly permeable subsoils.

N.B. The rainfall rates are calculated using the location specific values above in accordance with the Wallingford procedure.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 10 Year (+40%) Soakaway Calculations**

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Rectangular pit design data:-

Pit length	= 15 m	Pit width	= 6.5 m
Depth below invert	= 2 m	Percentage voids	= 30.0%
Imperm. area	= 1000 m ²	Infilt. factor	= 0.00003 m/s
Return period	= 10 yrs	Climate change	= 40%

Calculations :-

Surface area of soakaway to 50% storage depth (not inc. base):-

$$a_{s50} = 2 \times (\text{length} + \text{width}) \times \text{depth}/2 = 43.0 \text{ m}^2$$

Outflow factor : $O = a_{s50} \times \text{Infiltration rate} = 0.00129 \text{ m/s}$

Soakaway storage volume : $S_{\text{actual}} = \text{length} \times \text{width} \times \text{depth} \times \% \text{voids}/100 = 58.5 \text{ m}^3$

Duration	Rainfall mm/hr	Inflow m ³	Depth (hmax) m	Outflow m ³	Storage m ³
5 mins	124.0	10.3	0.34	0.39	9.91
10 mins	90.7	15.1	0.49	0.77	14.28
15 mins	72.8	18.2	0.58	1.16	17.03
30 mins	47.8	23.9	0.74	2.32	21.59
1 hrs	30.2	30.2	0.87	4.64	25.56
2 hrs	18.6	37.3	0.96	9.29	27.97
4 hrs	11.3	45.2	0.91	18.58	26.66
6 hrs	8.4	50.4	0.77	27.86	22.52
10 hrs	5.8	57.6	0.38	46.44	11.20
24 hrs	3.0	72.3	0.00	111.46	0.00

Actual volume : $S_{\text{actual}} = 58.500 \text{ m}^3$

Required volume : $S_{\text{reqd.}} = 27.970 \text{ m}^3$

Soakaway volume storage OK.

Minimum required a_{s50} : 20.56 m²

Actual a_{s50} : 43.00 m²

Minimum depth required: 0.96 m

Time to maximum 2 hrs

Emptying time to 50% volume = $t_{s50} = S_{\text{reqd}} \times 0.5 / (a_{s50} \times \text{Infiltration rate}) = 03:00 \text{ (hr:min)}$

Soakaway emptying time is OK.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 10 Year (+40%) Soakaway Calculations**

Location hydrological data (FSR):-

Location	= GLYN CEIRIOG	Grid reference	= SJ2038
M5-60 (mm)	= 18	r	= 0.36
Soil index	= 0.30	SAAR (mm/yr)	= 1150
WRAP	= 2	Area	= England and Wales

Soil classification for WRAP type 2

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils;
- iii) Moderately permeable soils, some with slowly permeable subsoils.

N.B. The rainfall rates are calculated using the location specific values above in accordance with the Wallingford procedure.

APPENDIX 2 – Storage Calculations: Assuming No Infiltration



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 100 Year (+40%) Attenuation Storage Calculations**

Data:-

Location = GLYN CEIRIOG Grid reference = SJ2038
M5-60 (mm) = 18 r = 0.36
Soil index = 0.30 SAAR (mm/yr) = 1150
Return period = 100 WRAP = 2
UCWI = 0.0 Climate change = 40%

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils; The layer is low in organic matter, mottled and (fragipan - a natural subsurface horizon having a higher bulk density than the solum above. Seemingly cemented when dry but showing moderate to weak brittleness when moist. Slowly or very slowly permeable to water. It is found in profiles of either cultivated or virgin soils but not in calcareous material).
- iii) Moderately permeable soils, some with slowly permeable subsoils.

Pipeline storage = 0.0 m³ Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 100.0% (manual setting)

Imperv. area = 1000 m² Pervious area = 0 m²
Total area = 1000 m² Equiv area = 1000 m² (Tot. area x % runoff).
Total runoff = 62.9 m³ Discharge rate = 5.000 l/s
Storage (m³) = 35.5 m³ (Sum of all balance quantities)

Total rainfall depth = 62.9 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.020	20.0	6.3	0.126	0.360	0.000	0.000
0.040	20.0	6.3	0.126	0.360	0.000	0.000
0.060	21.0	6.6	0.132	0.360	0.000	0.000
0.080	21.0	6.6	0.132	0.360	0.000	0.000
0.100	22.0	6.9	0.138	0.360	0.000	0.000
0.120	23.0	7.2	0.145	0.360	0.000	0.000
0.140	24.0	7.6	0.151	0.360	0.000	0.000
0.160	26.0	8.2	0.164	0.360	0.000	0.000
0.180	27.0	8.5	0.170	0.360	0.000	0.000
0.200	29.0	9.1	0.183	0.360	0.000	0.000
0.220	31.0	9.8	0.195	0.360	0.000	0.000
0.240	32.0	10.1	0.201	0.360	0.000	0.000
0.260	33.0	10.4	0.208	0.360	0.000	0.000
0.280	34.0	10.7	0.214	0.360	0.000	0.000
0.300	36.0	11.3	0.227	0.360	0.000	0.000
0.320	38.0	12.0	0.239	0.360	0.000	0.000
0.340	39.0	12.3	0.245	0.360	0.000	0.000
0.360	40.0	12.6	0.252	0.360	0.000	0.000
0.380	42.0	13.2	0.264	0.360	0.000	0.000
0.400	45.0	14.2	0.283	0.360	0.000	0.000
0.420	49.0	15.4	0.308	0.360	0.000	0.000
0.440	53.0	16.7	0.334	0.360	0.000	0.000
0.460	57.0	17.9	0.359	0.360	0.000	0.000
0.480	62.0	19.5	0.390	0.360	0.030	0.030
0.500	66.0	20.8	0.415	0.360	0.055	0.086
0.520	71.0	22.3	0.447	0.360	0.087	0.172
0.540	77.0	24.2	0.485	0.360	0.125	0.297
0.560	84.0	26.4	0.529	0.360	0.169	0.466
0.580	91.0	28.6	0.573	0.360	0.213	0.678
0.600	98.0	30.8	0.617	0.360	0.257	0.935
0.620	105.0	33.0	0.661	0.360	0.301	1.236
0.640	114.0	35.9	0.717	0.360	0.357	1.594
0.660	125.0	39.3	0.787	0.360	0.427	2.020
0.680	135.0	42.5	0.850	0.360	0.490	2.510
0.700	143.0	45.0	0.900	0.360	0.540	3.050
0.720	154.0	48.5	0.969	0.360	0.609	3.659



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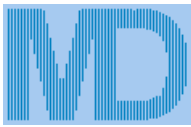
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Title **1 in 100 Year (+40%) Attenuation Storage Calculations**

Calculations (cont.) :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.820	204.0	64.2	1.284	0.360	0.924	7.637
0.840	212.0	66.7	1.334	0.360	0.974	8.611
0.860	219.0	68.9	1.378	0.360	1.018	9.629
0.880	226.0	71.1	1.422	0.360	1.062	10.692
0.900	233.0	73.3	1.466	0.360	1.106	11.798
0.920	239.0	75.2	1.504	0.360	1.144	12.942
0.940	244.0	76.8	1.536	0.360	1.176	14.118
0.960	248.0	78.0	1.561	0.360	1.201	15.319
0.980	249.0	78.4	1.567	0.360	1.207	16.526
1.000	250.0	78.7	1.573	0.360	1.213	17.739
1.020	250.0	78.7	1.573	0.360	1.213	18.953
1.040	249.0	78.4	1.567	0.360	1.207	20.160
1.060	248.0	78.0	1.561	0.360	1.201	21.360
1.080	244.0	76.8	1.536	0.360	1.176	22.536
1.100	239.0	75.2	1.504	0.360	1.144	23.680
1.120	233.0	73.3	1.466	0.360	1.106	24.787
1.140	226.0	71.1	1.422	0.360	1.062	25.849
1.160	219.0	68.9	1.378	0.360	1.018	26.867
1.180	212.0	66.7	1.334	0.360	0.974	27.842
1.200	204.0	64.2	1.284	0.360	0.924	28.766
1.220	194.0	61.0	1.221	0.360	0.861	29.627
1.240	183.0	57.6	1.152	0.360	0.792	30.418
1.260	173.0	54.4	1.089	0.360	0.729	31.147
1.280	164.0	51.6	1.032	0.360	0.672	31.819
1.300	154.0	48.5	0.969	0.360	0.609	32.428
1.320	143.0	45.0	0.900	0.360	0.540	32.968
1.340	135.0	42.5	0.850	0.360	0.490	33.458
1.360	125.0	39.3	0.787	0.360	0.427	33.885
1.380	114.0	35.9	0.717	0.360	0.357	34.242
1.400	105.0	33.0	0.661	0.360	0.301	34.543
1.420	98.0	30.8	0.617	0.360	0.257	34.800
1.440	91.0	28.6	0.573	0.360	0.213	35.013
1.460	84.0	26.4	0.529	0.360	0.169	35.181
1.480	77.0	24.2	0.485	0.360	0.125	35.306
1.500	71.0	22.3	0.447	0.360	0.087	35.393
1.520	66.0	20.8	0.415	0.360	0.055	35.448
1.540	62.0	19.5	0.390	0.360	0.030	35.478
1.560	57.0	17.9	0.359	0.360	0.000	35.477
1.580	53.0	16.7	0.334	0.360	0.000	35.451
1.600	49.0	15.4	0.308	0.360	0.000	35.399
1.620	45.0	14.2	0.283	0.360	0.000	35.322
1.640	42.0	13.2	0.264	0.360	0.000	35.227
1.660	40.0	12.6	0.252	0.360	0.000	35.118
1.680	39.0	12.3	0.245	0.360	0.000	35.004
1.700	38.0	12.0	0.239	0.360	0.000	34.883
1.720	36.0	11.3	0.227	0.360	0.000	34.749
1.740	34.0	10.7	0.214	0.360	0.000	34.603
1.760	33.0	10.4	0.208	0.360	0.000	34.451
1.780	32.0	10.1	0.201	0.360	0.000	34.293
1.800	31.0	9.8	0.195	0.360	0.000	34.128
1.820	29.0	9.1	0.183	0.360	0.000	33.950
1.840	27.0	8.5	0.170	0.360	0.000	33.760
1.860	26.0	8.2	0.164	0.360	0.000	33.564
1.880	24.0	7.6	0.151	0.360	0.000	33.355
1.900	23.0	7.2	0.145	0.360	0.000	33.139
1.920	22.0	6.9	0.138	0.360	0.000	32.918
1.940	21.0	6.6	0.132	0.360	0.000	32.690
1.960	21.0	6.6	0.132	0.360	0.000	32.462
1.980	20.0	6.3	0.126	0.360	0.000	32.228
2.000	20.0	6.3	0.126	0.360	0.000	31.994

Storage volume (m³) = 35.5 m³ (Sum of all balance quantities)



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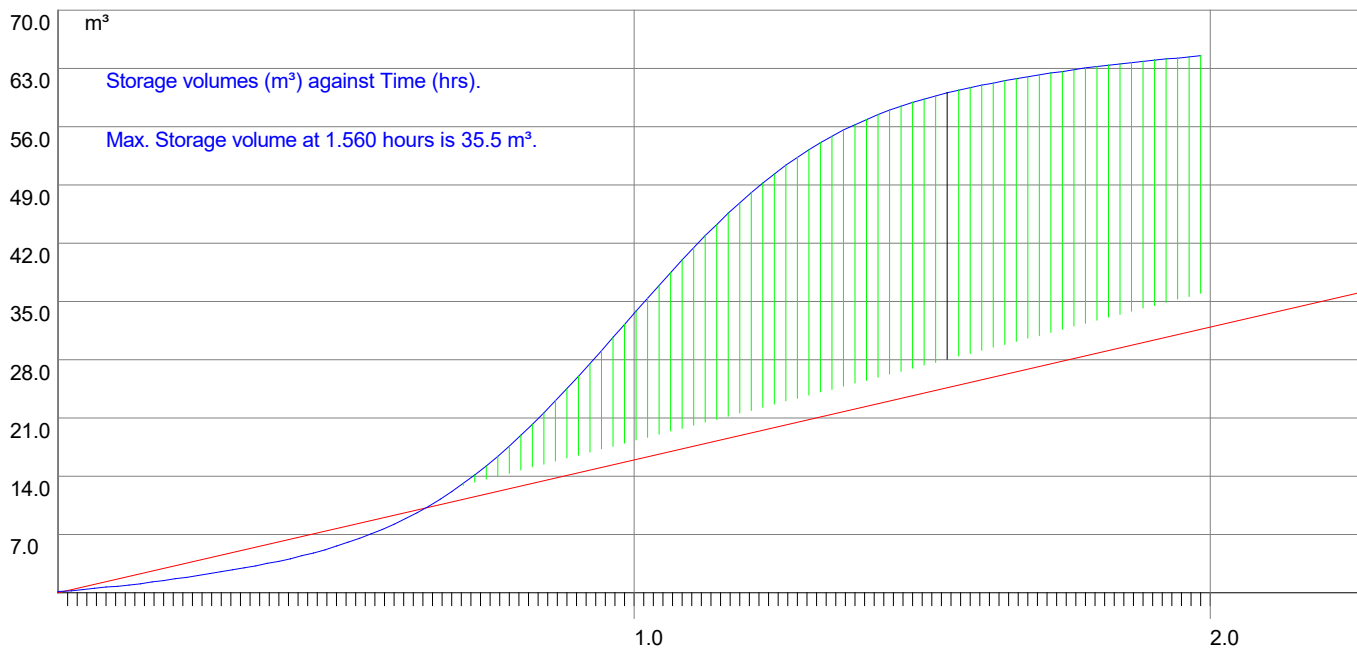
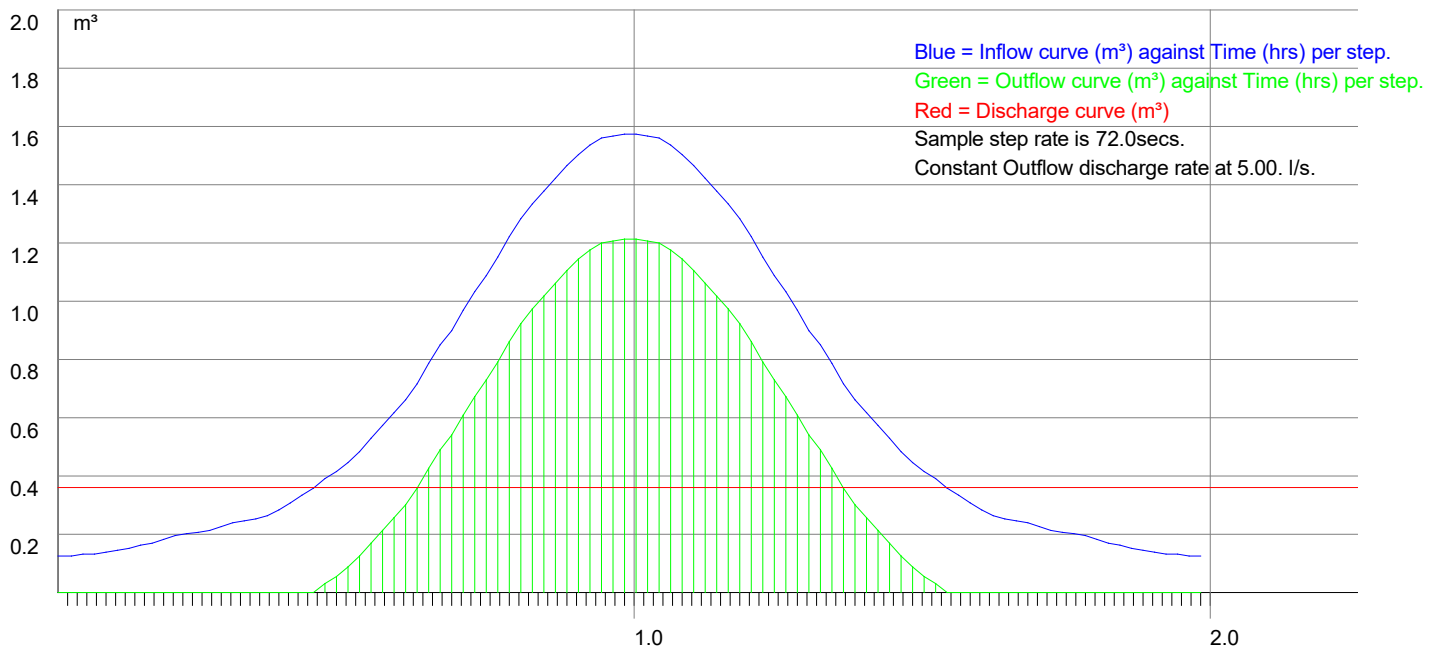
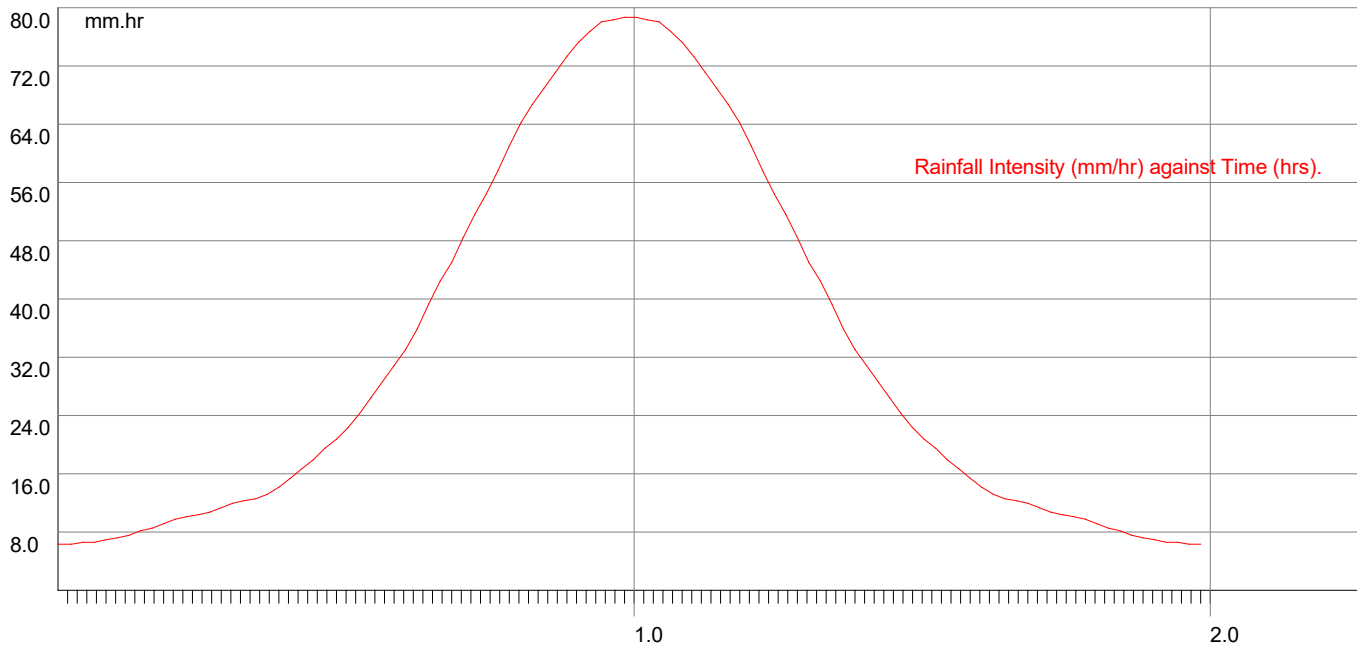
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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 100 Year (+40%) Attenuation Storage Calculations**

Maximum storage volumes for varying duration storms.

Storm length (hrs)	Max. Vol (m ³)	Max. Vol time	Mean intens (mm/hr)	Step time. (mins)	Peak found
0.25	25.89	0.25	118.61	0.2	
0.5	31.77	0.50	79.41	0.3	
1	35.43	1.00	50.81	0.6	
2	35.48	2.00	31.47	1.2	Peak found
3	32.71	---	23.47	1.8	
4	29.03	---	18.94	2.4	
5	25.06	---	15.98	3.0	
6	21.08	---	13.88	3.6	
7	17.35	---	12.34	4.2	
8	13.84	---	11.14	4.8	
9	10.61	---	10.18	5.4	
10	7.68	---	9.39	6.0	
12	2.83	---	8.16	7.2	
15	0.00	---	6.87	9.0	
18	0.00	---	5.96	10.8	
20	0.00	---	5.49	12.0	
24	0.00	---	4.76	14.4	
30	0.00	---	4.00	18.0	
36	0.00	---	3.47	21.6	
42	0.00	---	3.07	25.2	
48	0.00	---	2.77	28.8	
54	0.00	---	2.52	32.4	
60	0.00	---	2.32	36.0	
66	0.00	---	2.15	39.6	
72	0.00	---	2.01	43.2	
84	0.00	---	1.78	50.4	
96	0.00	---	1.60	57.6	
120	0.00	---	1.34	72.0	
150	0.00	---	1.12	90.0	
175	0.00	---	0.99	105.0	
200	0.00	---	0.89	120.0	
250	0.00	---	0.74	150.0	
300	0.00	---	0.64	180.0	
375	0.00	---	0.54	225.0	
500	0.00	---	0.43	300.0	
750	0.00	---	0.31	450.0	
1000	0.00	---	0.25	600.0	
1250	0.00	---	0.21	750.0	
1500	0.00	---	0.18	900.0	
1570	0.00	---	0.18	942.0	
2000	0.00	---	0.15	1200.0	
2500	0.00	---	0.12	1500.0	
3000	0.00	---	0.11	1800.0	
3500	0.00	---	0.10	2100.0	
4000	0.00	---	0.09	2400.0	



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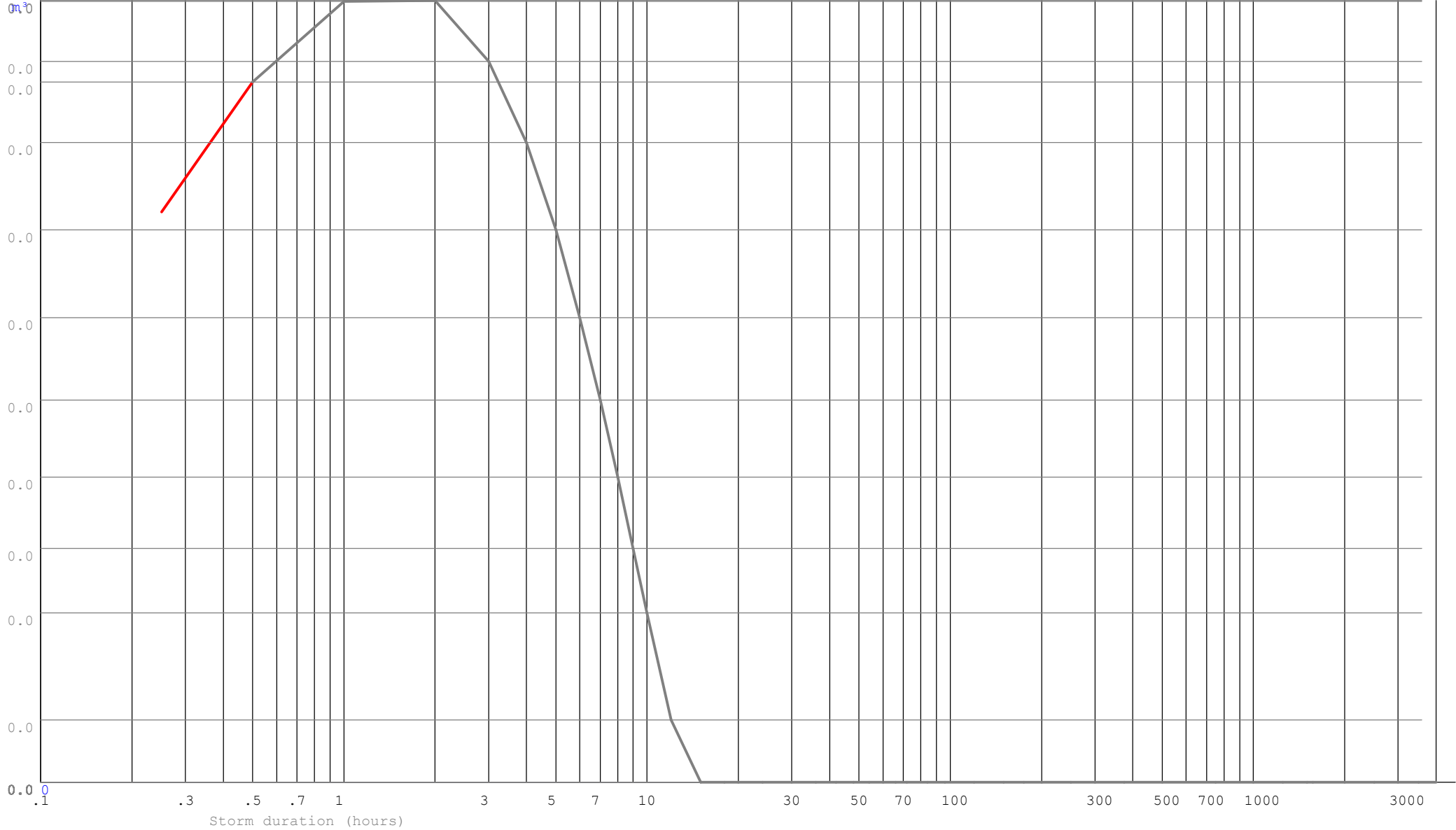
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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 100 Year (+40%) Attenuation Storage Calculations**

Sequential storage volume at specific storm durations.





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Project Land behind Sion Chapel, Pontfadog, LL20 7AS				By	Checked	Reviewed
Title 1 in 100 Year (+40%) Attenuation Storage Calculations						

Explanatory notes for Peak Flow Storage

- 1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
- 2) The balance is calculated from the inflow minus the outflow.
- 3) The storage volume is the maximum value of the balance curve.
- 4) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
- 5) References to 'storm duration' relate only to the hydrograph method (qv).
- 6) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

- 1) The user has the choice of Summer or Winter curves
- 2) The mean intensity varies with the duration of the storm curve
- 3) There are always 120 steps in the calculation process, irrespective of storm duration.
- 4) The balance is calculated from the inflow minus the outflow.
- 5) The storage volume is the sum of the balance values for each step.
- 6) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function.
Please be aware that this function needs the full design data file to function.

Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

It can be seen that these two methods are very different, and the user may have the choice of which result to use. This is not an exact science, though is often treated as such by those that do not understand the principles of the calculations.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Attenuation Storage Calculations**

Data:-

Location = GLYN CEIRIOG Grid reference = SJ2038
M5-60 (mm) = 18 r = 0.36
Soil index = 0.30 SAAR (mm/yr) = 1150
Return period = 30 WRAP = 2
UCWI = 0.0 Climate change = 40%

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils; The layer is low in organic matter, mottled and (fragipan - a natural subsurface horizon having a higher bulk density than the solum above. Seemingly cemented when dry but showing moderate to weak brittleness when moist. Slowly or very slowly permeable to water. It is found in profiles of either cultivated or virgin soils but not in calcareous material).
- iii) Moderately permeable soils, some with slowly permeable subsoils.

Pipeline storage = 0.0 m³ Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 100.0% (manual setting)

Imperv. area = 1000 m² Pervious area = 0 m²
Total area = 1000 m² Equiv area = 1000 m² (Tot. area x % runoff).
Total runoff = 38.7 m³ Discharge rate = 5.000 l/s
Storage (m³) = 24.2 m³ (Sum of all balance quantities)

Total rainfall depth = 38.7 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.010	20.0	7.7	0.077	0.180	0.000	0.000
0.020	20.0	7.7	0.077	0.180	0.000	0.000
0.030	21.0	8.1	0.081	0.180	0.000	0.000
0.040	21.0	8.1	0.081	0.180	0.000	0.000
0.050	22.0	8.5	0.085	0.180	0.000	0.000
0.060	23.0	8.9	0.089	0.180	0.000	0.000
0.070	24.0	9.3	0.093	0.180	0.000	0.000
0.080	26.0	10.1	0.101	0.180	0.000	0.000
0.090	27.0	10.5	0.105	0.180	0.000	0.000
0.100	29.0	11.2	0.112	0.180	0.000	0.000
0.110	31.0	12.0	0.120	0.180	0.000	0.000
0.120	32.0	12.4	0.124	0.180	0.000	0.000
0.130	33.0	12.8	0.128	0.180	0.000	0.000
0.140	34.0	13.2	0.132	0.180	0.000	0.000
0.150	36.0	13.9	0.139	0.180	0.000	0.000
0.160	38.0	14.7	0.147	0.180	0.000	0.000
0.170	39.0	15.1	0.151	0.180	0.000	0.000
0.180	40.0	15.5	0.155	0.180	0.000	0.000
0.190	42.0	16.3	0.163	0.180	0.000	0.000
0.200	45.0	17.4	0.174	0.180	0.000	0.000
0.210	49.0	19.0	0.190	0.180	0.010	0.010
0.220	53.0	20.5	0.205	0.180	0.025	0.035
0.230	57.0	22.1	0.221	0.180	0.041	0.076
0.240	62.0	24.0	0.240	0.180	0.060	0.136
0.250	66.0	25.6	0.256	0.180	0.076	0.211
0.260	71.0	27.5	0.275	0.180	0.095	0.306
0.270	77.0	29.8	0.298	0.180	0.118	0.424
0.280	84.0	32.5	0.325	0.180	0.145	0.569
0.290	91.0	35.2	0.352	0.180	0.172	0.742
0.300	98.0	37.9	0.379	0.180	0.199	0.941
0.310	105.0	40.7	0.407	0.180	0.227	1.168
0.320	114.0	44.1	0.441	0.180	0.261	1.429
0.330	125.0	48.4	0.484	0.180	0.304	1.733
0.340	135.0	52.3	0.523	0.180	0.343	2.075
0.350	143.0	55.4	0.554	0.180	0.374	2.449
0.360	154.0	59.6	0.596	0.180	0.416	2.865



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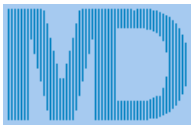
Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Attenuation Storage Calculations**

Calculations (cont.) :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.410	204.0	79.0	0.790	0.180	0.610	5.519
0.420	212.0	82.1	0.821	0.180	0.641	6.160
0.430	219.0	84.8	0.848	0.180	0.668	6.828
0.440	226.0	87.5	0.875	0.180	0.695	7.523
0.450	233.0	90.2	0.902	0.180	0.722	8.245
0.460	239.0	92.5	0.925	0.180	0.745	8.990
0.470	244.0	94.5	0.945	0.180	0.765	9.755
0.480	248.0	96.0	0.960	0.180	0.780	10.535
0.490	249.0	96.4	0.964	0.180	0.784	11.319
0.500	250.0	96.8	0.968	0.180	0.788	12.107
0.510	250.0	96.8	0.968	0.180	0.788	12.895
0.520	249.0	96.4	0.964	0.180	0.784	13.679
0.530	248.0	96.0	0.960	0.180	0.780	14.459
0.540	244.0	94.5	0.945	0.180	0.765	15.223
0.550	239.0	92.5	0.925	0.180	0.745	15.969
0.560	233.0	90.2	0.902	0.180	0.722	16.691
0.570	226.0	87.5	0.875	0.180	0.695	17.386
0.580	219.0	84.8	0.848	0.180	0.668	18.054
0.590	212.0	82.1	0.821	0.180	0.641	18.694
0.600	204.0	79.0	0.790	0.180	0.610	19.304
0.610	194.0	75.1	0.751	0.180	0.571	19.875
0.620	183.0	70.8	0.708	0.180	0.528	20.404
0.630	173.0	67.0	0.670	0.180	0.490	20.893
0.640	164.0	63.5	0.635	0.180	0.455	21.348
0.650	154.0	59.6	0.596	0.180	0.416	21.765
0.660	143.0	55.4	0.554	0.180	0.374	22.138
0.670	135.0	52.3	0.523	0.180	0.343	22.481
0.680	125.0	48.4	0.484	0.180	0.304	22.785
0.690	114.0	44.1	0.441	0.180	0.261	23.046
0.700	105.0	40.7	0.407	0.180	0.227	23.273
0.710	98.0	37.9	0.379	0.180	0.199	23.472
0.720	91.0	35.2	0.352	0.180	0.172	23.644
0.730	84.0	32.5	0.325	0.180	0.145	23.789
0.740	77.0	29.8	0.298	0.180	0.118	23.908
0.750	71.0	27.5	0.275	0.180	0.095	24.002
0.760	66.0	25.6	0.256	0.180	0.076	24.078
0.770	62.0	24.0	0.240	0.180	0.060	24.138
0.780	57.0	22.1	0.221	0.180	0.041	24.179
0.790	53.0	20.5	0.205	0.180	0.025	24.204
0.800	49.0	19.0	0.190	0.180	0.010	24.214
0.810	45.0	17.4	0.174	0.180	0.000	24.208
0.820	42.0	16.3	0.163	0.180	0.000	24.190
0.830	40.0	15.5	0.155	0.180	0.000	24.165
0.840	39.0	15.1	0.151	0.180	0.000	24.136
0.850	38.0	14.7	0.147	0.180	0.000	24.103
0.860	36.0	13.9	0.139	0.180	0.000	24.063
0.870	34.0	13.2	0.132	0.180	0.000	24.014
0.880	33.0	12.8	0.128	0.180	0.000	23.962
0.890	32.0	12.4	0.124	0.180	0.000	23.906
0.900	31.0	12.0	0.120	0.180	0.000	23.846
0.910	29.0	11.2	0.112	0.180	0.000	23.778
0.920	27.0	10.5	0.105	0.180	0.000	23.703
0.930	26.0	10.1	0.101	0.180	0.000	23.623
0.940	24.0	9.3	0.093	0.180	0.000	23.536
0.950	23.0	8.9	0.089	0.180	0.000	23.445
0.960	22.0	8.5	0.085	0.180	0.000	23.351
0.970	21.0	8.1	0.081	0.180	0.000	23.252
0.980	21.0	8.1	0.081	0.180	0.000	23.153
0.990	20.0	7.7	0.077	0.180	0.000	23.051
1.000	20.0	7.7	0.077	0.180	0.000	22.948

Storage volume (m³) = 24.2 m³ (Sum of all balance quantities)



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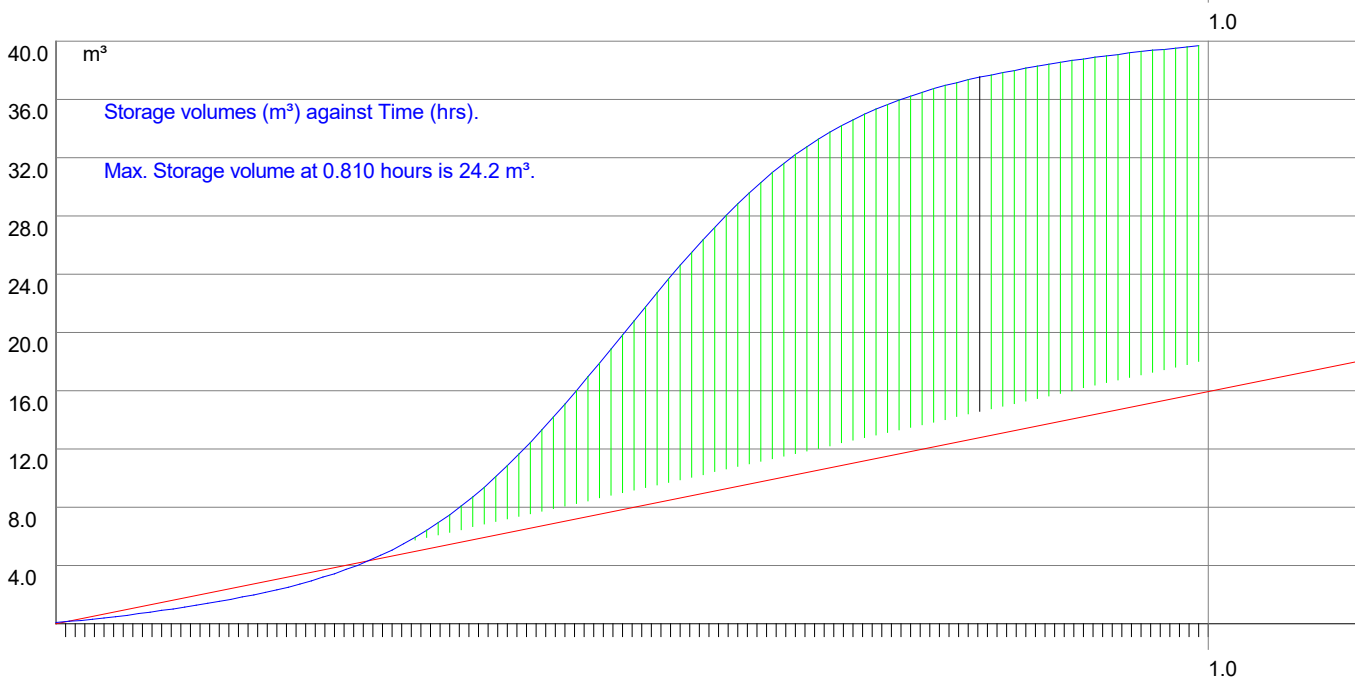
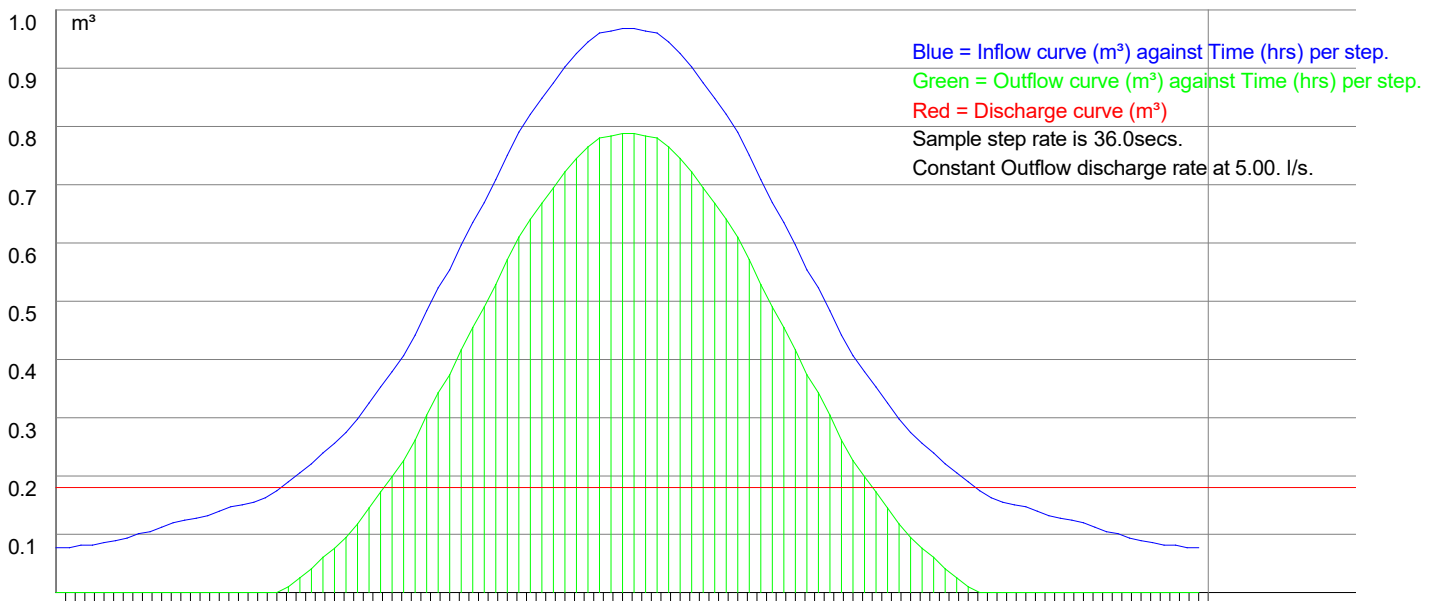
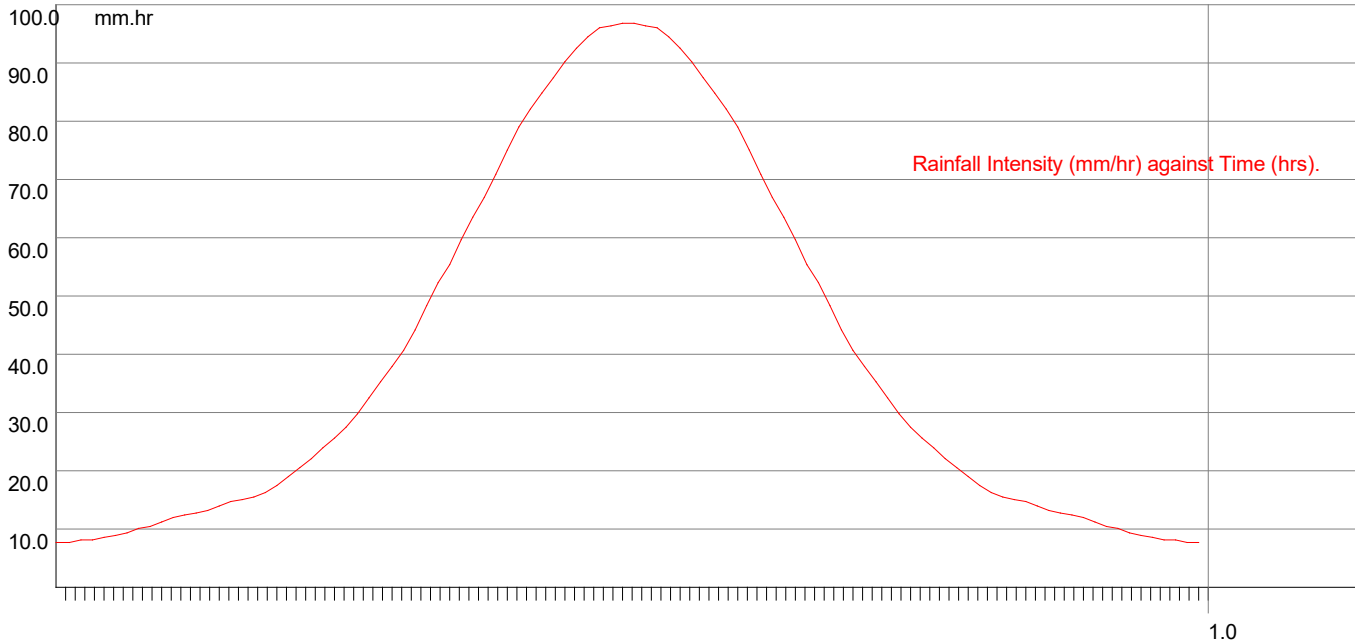
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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Attenuation Storage Calculations**





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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Attenuation Storage Calculations**

Maximum storage volumes for varying duration storms.

Storm length (hrs)	Max. Vol (m ³)	Max. Vol time	Mean intens (mm/hr)	Step time. (mins)	Peak found
0.25	19.04	0.25	91.87	0.2	
0.5	22.60	0.50	60.91	0.3	
1	24.21	1.00	38.71	0.6	Peak found
2	22.57	---	23.92	1.2	
3	19.29	---	17.87	1.8	
4	15.68	---	14.46	2.4	
5	12.08	---	12.24	3.0	
6	8.73	---	10.67	3.6	
7	5.81	---	9.51	4.2	
8	3.26	---	8.60	4.8	
9	1.30	---	7.87	5.4	
10	0.07	---	7.27	6.0	
12	0.00	---	6.34	7.2	
15	0.00	---	5.36	9.0	
18	0.00	---	4.66	10.8	
20	0.00	---	4.31	12.0	
24	0.00	---	3.75	14.4	
30	0.00	---	3.16	18.0	
36	0.00	---	2.75	21.6	
42	0.00	---	2.44	25.2	
48	0.00	---	2.21	28.8	
54	0.00	---	2.02	32.4	
60	0.00	---	1.86	36.0	
66	0.00	---	1.73	39.6	
72	0.00	---	1.62	43.2	
84	0.00	---	1.44	50.4	
96	0.00	---	1.29	57.6	
120	0.00	---	1.09	72.0	
150	0.00	---	0.92	90.0	
175	0.00	---	0.81	105.0	
200	0.00	---	0.73	120.0	
250	0.00	---	0.62	150.0	
300	0.00	---	0.54	180.0	
375	0.00	---	0.45	225.0	
500	0.00	---	0.36	300.0	
750	0.00	---	0.27	450.0	
1000	0.00	---	0.21	600.0	
1250	0.00	---	0.18	750.0	
1500	0.00	---	0.16	900.0	
1570	0.00	---	0.15	942.0	
2000	0.00	---	0.13	1200.0	
2500	0.00	---	0.11	1500.0	
3000	0.00	---	0.09	1800.0	
3500	0.00	---	0.08	2100.0	
4000	0.00	---	0.08	2400.0	



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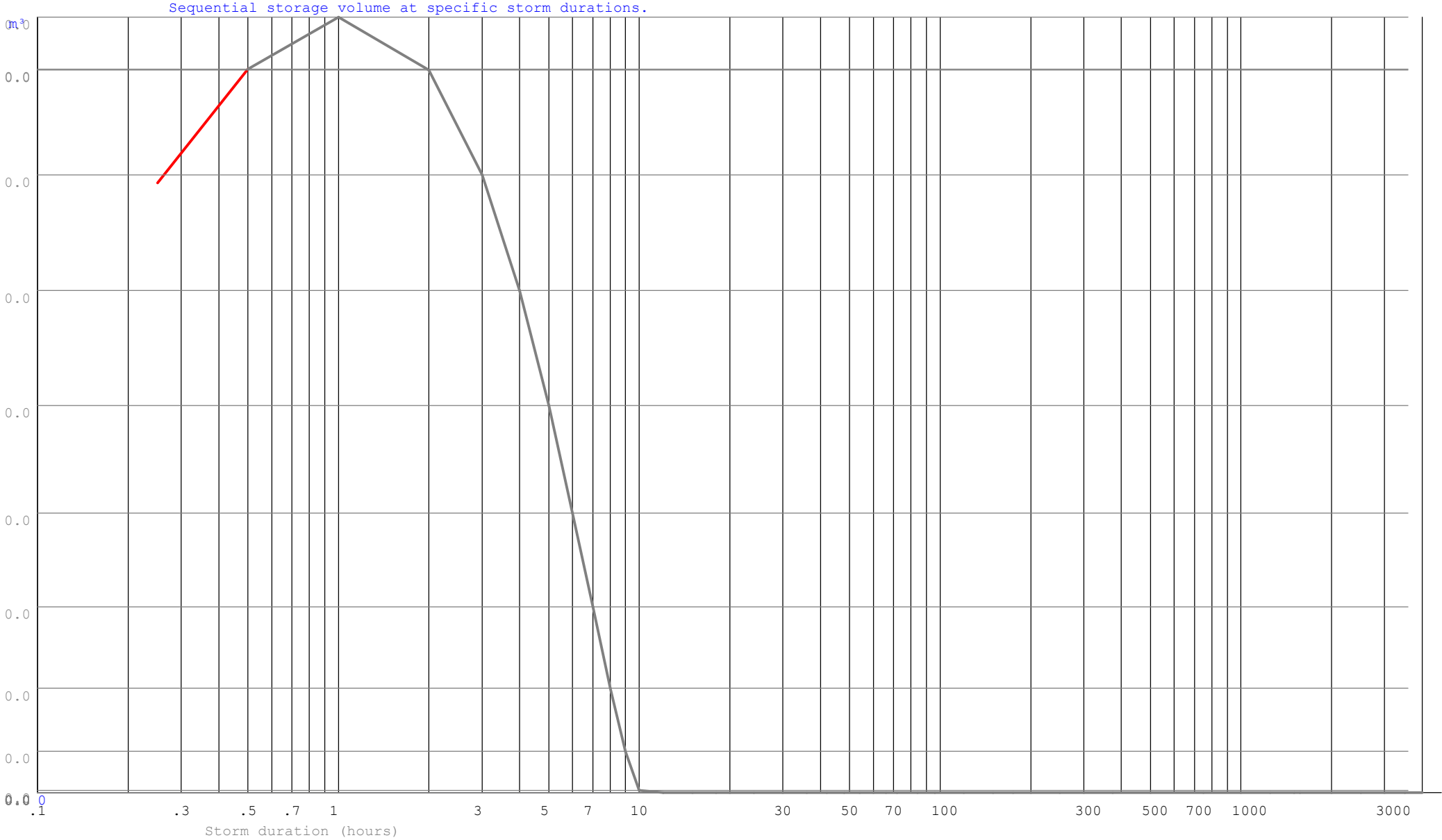
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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 30 Year (+40%) Attenuation Storage Calculations**





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Title	1 in 30 Year (+40%) Attenuation Storage Calculations					

Explanatory notes for Peak Flow Storage

- 1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
- 2) The balance is calculated from the inflow minus the outflow.
- 3) The storage volume is the maximum value of the balance curve.
- 4) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
- 5) References to 'storm duration' relate only to the hydrograph method (qv).
- 6) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

- 1) The user has the choice of Summer or Winter curves
- 2) The mean intensity varies with the duration of the storm curve
- 3) There are always 120 steps in the calculation process, irrespective of storm duration.
- 4) The balance is calculated from the inflow minus the outflow.
- 5) The storage volume is the sum of the balance values for each step.
- 6) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function.
Please be aware that this function needs the full design data file to function.

Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

It can be seen that these two methods are very different, and the user may have the choice of which result to use. This is not an exact science, though is often treated as such by those that do not understand the principles of the calculations.



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 2 Year (+40%) Attenuation Storage Calculations**

Data:-

Location = GLYN CEIRIOG Grid reference = SJ2038
M5-60 (mm) = 18 r = 0.36
Soil index = 0.30 SAAR (mm/yr) = 1150
Return period = 2 WRAP = 2
UCWI = 0.0 Climate change = 40%

- i) Very permeable soils with shallow ground water;
- ii) Permeable soils over rock or fragipan, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils; The layer is low in organic matter, mottled and (fragipan - a natural subsurface horizon having a higher bulk density than the solum above. Seemingly cemented when dry but showing moderate to weak brittleness when moist. Slowly or very slowly permeable to water. It is found in profiles of either cultivated or virgin soils but not in calcareous material).
- iii) Moderately permeable soils, some with slowly permeable subsoils.

Pipeline storage = 0.0 m³ Available MH storage = 0.0 m³
Offline storage = 0.0 m³

Percentage runoff = 100.0% (manual setting)

Imperv. area = 1000 m² Pervious area = 0 m²
Total area = 1000 m² Equiv area = 1000 m² (Tot. area x % runoff).
Total runoff = 16.8 m³ Discharge rate = 5.000 l/s
Storage (m³) = 9.8 m³ (Sum of all balance quantities)

Total rainfall depth = 16.8 mm

Calculations :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.005	20.0	6.7	0.034	0.090	0.000	0.000
0.010	20.0	6.7	0.034	0.090	0.000	0.000
0.015	21.0	7.0	0.035	0.090	0.000	0.000
0.020	21.0	7.0	0.035	0.090	0.000	0.000
0.025	22.0	7.4	0.037	0.090	0.000	0.000
0.030	23.0	7.7	0.039	0.090	0.000	0.000
0.035	24.0	8.0	0.040	0.090	0.000	0.000
0.040	26.0	8.7	0.044	0.090	0.000	0.000
0.045	27.0	9.1	0.045	0.090	0.000	0.000
0.050	29.0	9.7	0.049	0.090	0.000	0.000
0.055	31.0	10.4	0.052	0.090	0.000	0.000
0.060	32.0	10.7	0.054	0.090	0.000	0.000
0.065	33.0	11.1	0.055	0.090	0.000	0.000
0.070	34.0	11.4	0.057	0.090	0.000	0.000
0.075	36.0	12.1	0.060	0.090	0.000	0.000
0.080	38.0	12.7	0.064	0.090	0.000	0.000
0.085	39.0	13.1	0.065	0.090	0.000	0.000
0.090	40.0	13.4	0.067	0.090	0.000	0.000
0.095	42.0	14.1	0.070	0.090	0.000	0.000
0.100	45.0	15.1	0.075	0.090	0.000	0.000
0.105	49.0	16.4	0.082	0.090	0.000	0.000
0.110	53.0	17.8	0.089	0.090	0.000	0.000
0.115	57.0	19.1	0.096	0.090	0.006	0.006
0.120	62.0	20.8	0.104	0.090	0.014	0.020
0.125	66.0	22.1	0.111	0.090	0.021	0.040
0.130	71.0	23.8	0.119	0.090	0.029	0.069
0.135	77.0	25.8	0.129	0.090	0.039	0.108
0.140	84.0	28.2	0.141	0.090	0.051	0.159
0.145	91.0	30.5	0.153	0.090	0.063	0.222
0.150	98.0	32.9	0.164	0.090	0.074	0.296
0.155	105.0	35.2	0.176	0.090	0.086	0.382
0.160	114.0	38.2	0.191	0.090	0.101	0.483
0.165	125.0	41.9	0.210	0.090	0.120	0.603
0.170	135.0	45.3	0.226	0.090	0.136	0.739
0.175	143.0	48.0	0.240	0.090	0.150	0.889
0.180	154.0	51.6	0.258	0.090	0.168	1.058



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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 2 Year (+40%) Attenuation Storage Calculations**

Calculations (cont.) :-

Time (hrs)	%Mean intens	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)	Cumulative (m3)
0.205	204.0	68.4	0.342	0.090	0.252	2.147
0.210	212.0	71.1	0.356	0.090	0.266	2.412
0.215	219.0	73.4	0.367	0.090	0.277	2.690
0.220	226.0	75.8	0.379	0.090	0.289	2.979
0.225	233.0	78.1	0.391	0.090	0.301	3.279
0.230	239.0	80.2	0.401	0.090	0.311	3.590
0.235	244.0	81.8	0.409	0.090	0.319	3.909
0.240	248.0	83.2	0.416	0.090	0.326	4.235
0.245	249.0	83.5	0.418	0.090	0.328	4.563
0.250	250.0	83.8	0.419	0.090	0.329	4.892
0.255	250.0	83.8	0.419	0.090	0.329	5.221
0.260	249.0	83.5	0.418	0.090	0.328	5.549
0.265	248.0	83.2	0.416	0.090	0.326	5.875
0.270	244.0	81.8	0.409	0.090	0.319	6.194
0.275	239.0	80.2	0.401	0.090	0.311	6.505
0.280	233.0	78.1	0.391	0.090	0.301	6.805
0.285	226.0	75.8	0.379	0.090	0.289	7.094
0.290	219.0	73.4	0.367	0.090	0.277	7.372
0.295	212.0	71.1	0.356	0.090	0.266	7.637
0.300	204.0	68.4	0.342	0.090	0.252	7.889
0.305	194.0	65.1	0.325	0.090	0.235	8.125
0.310	183.0	61.4	0.307	0.090	0.217	8.341
0.315	173.0	58.0	0.290	0.090	0.200	8.542
0.320	164.0	55.0	0.275	0.090	0.185	8.727
0.325	154.0	51.6	0.258	0.090	0.168	8.895
0.330	143.0	48.0	0.240	0.090	0.150	9.045
0.335	135.0	45.3	0.226	0.090	0.136	9.181
0.340	125.0	41.9	0.210	0.090	0.120	9.301
0.345	114.0	38.2	0.191	0.090	0.101	9.402
0.350	105.0	35.2	0.176	0.090	0.086	9.488
0.355	98.0	32.9	0.164	0.090	0.074	9.562
0.360	91.0	30.5	0.153	0.090	0.063	9.625
0.365	84.0	28.2	0.141	0.090	0.051	9.676
0.370	77.0	25.8	0.129	0.090	0.039	9.715
0.375	71.0	23.8	0.119	0.090	0.029	9.744
0.380	66.0	22.1	0.111	0.090	0.021	9.765
0.385	62.0	20.8	0.104	0.090	0.014	9.779
0.390	57.0	19.1	0.096	0.090	0.006	9.784
0.395	53.0	17.8	0.089	0.090	0.000	9.783
0.400	49.0	16.4	0.082	0.090	0.000	9.775
0.405	45.0	15.1	0.075	0.090	0.000	9.761
0.410	42.0	14.1	0.070	0.090	0.000	9.741
0.415	40.0	13.4	0.067	0.090	0.000	9.718
0.420	39.0	13.1	0.065	0.090	0.000	9.694
0.425	38.0	12.7	0.064	0.090	0.000	9.667
0.430	36.0	12.1	0.060	0.090	0.000	9.638
0.435	34.0	11.4	0.057	0.090	0.000	9.605
0.440	33.0	11.1	0.055	0.090	0.000	9.570
0.445	32.0	10.7	0.054	0.090	0.000	9.534
0.450	31.0	10.4	0.052	0.090	0.000	9.496
0.455	29.0	9.7	0.049	0.090	0.000	9.454
0.460	27.0	9.1	0.045	0.090	0.000	9.410
0.465	26.0	8.7	0.044	0.090	0.000	9.363
0.470	24.0	8.0	0.040	0.090	0.000	9.313
0.475	23.0	7.7	0.039	0.090	0.000	9.262
0.480	22.0	7.4	0.037	0.090	0.000	9.209
0.485	21.0	7.0	0.035	0.090	0.000	9.154
0.490	21.0	7.0	0.035	0.090	0.000	9.099
0.495	20.0	6.7	0.034	0.090	0.000	9.043
0.500	20.0	6.7	0.034	0.090	0.000	8.986

Storage volume (m³) = 9.8 m³ (Sum of all balance quantities)



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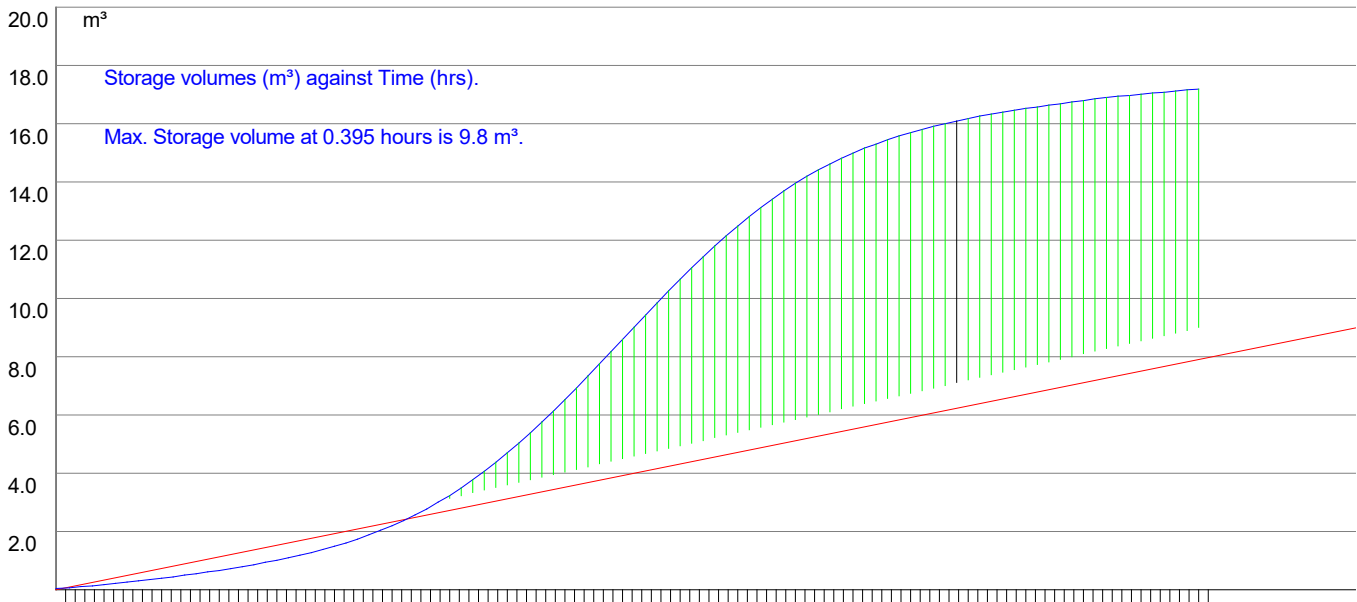
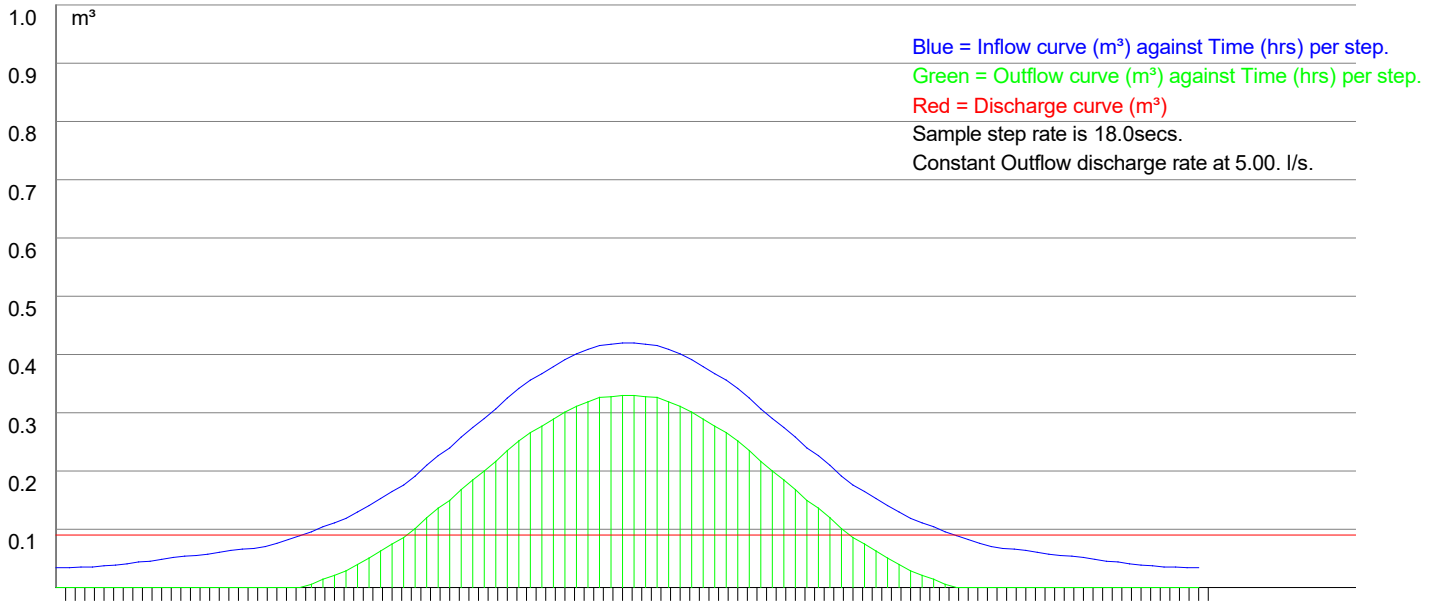
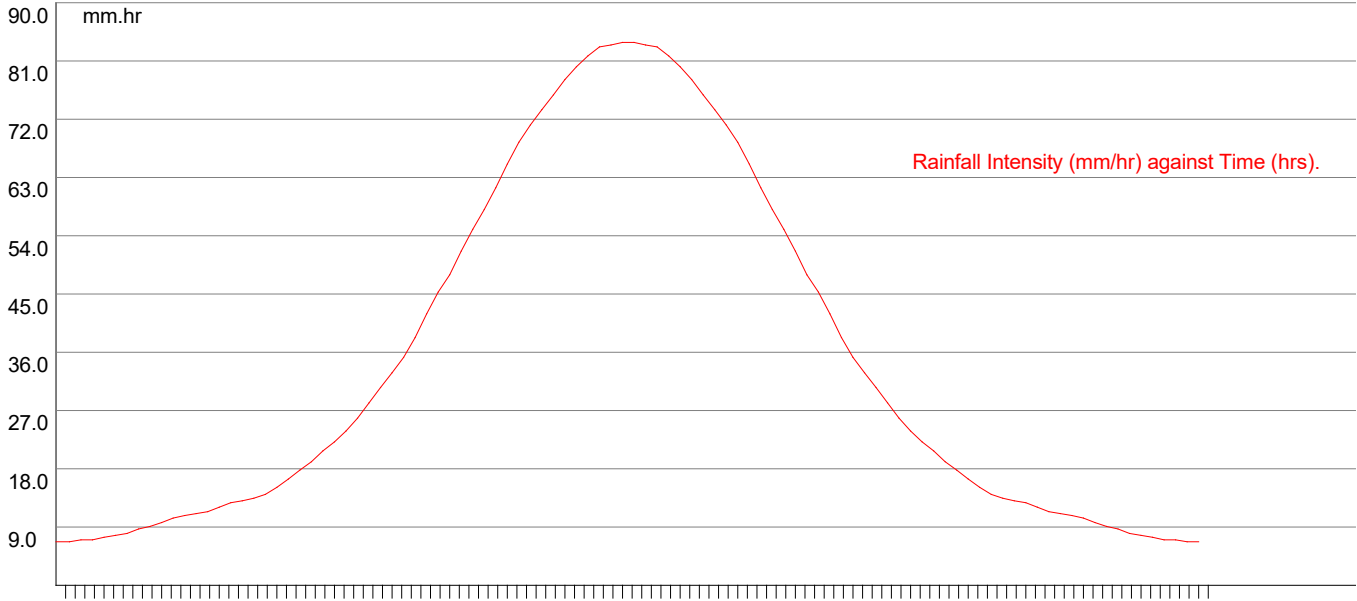
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1 in 2 Year (+40%) Attenuation Storage Calculations

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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 2 Year (+40%) Attenuation Storage Calculations**

Maximum storage volumes for varying duration storms.

Storm length (hrs)	Max. Vol (m ³)	Max. Vol time	Mean intens (mm/hr)	Step time. (mins)	Peak found
0.25	9.07	0.25	51.72	0.2	
0.5	9.78	0.50	33.54	0.3	Peak found
1	8.89	---	21.00	0.6	
2	5.71	---	12.91	1.2	
3	2.75	---	9.68	1.8	
4	0.59	---	7.89	2.4	
5	0.00	---	6.73	3.0	
6	0.00	---	5.91	3.6	
7	0.00	---	5.29	4.2	
8	0.00	---	4.81	4.8	
9	0.00	---	4.42	5.4	
10	0.00	---	4.10	6.0	
12	0.00	---	3.60	7.2	
15	0.00	---	3.06	9.0	
18	0.00	---	2.69	10.8	
20	0.00	---	2.49	12.0	
24	0.00	---	2.19	14.4	
30	0.00	---	1.86	18.0	
36	0.00	---	1.63	21.6	
42	0.00	---	1.46	25.2	
48	0.00	---	1.33	28.8	
54	0.00	---	1.22	32.4	
60	0.00	---	1.13	36.0	
66	0.00	---	1.06	39.6	
72	0.00	---	0.99	43.2	
84	0.00	---	0.89	50.4	
96	0.00	---	0.81	57.6	
120	0.00	---	0.69	72.0	
150	0.00	---	0.59	90.0	
175	0.00	---	0.53	105.0	
200	0.00	---	0.48	120.0	
250	0.00	---	0.41	150.0	
300	0.00	---	0.36	180.0	
375	0.00	---	0.30	225.0	
500	0.00	---	0.25	300.0	
750	0.00	---	0.19	450.0	
1000	0.00	---	0.15	600.0	
1250	0.00	---	0.13	750.0	
1500	0.00	---	0.11	900.0	
1570	0.00	---	0.11	942.0	
2000	0.00	---	0.09	1200.0	
2500	0.00	---	0.08	1500.0	
3000	0.00	---	0.07	1800.0	
3500	0.00	---	0.06	2100.0	
4000	0.00	---	0.06	2400.0	



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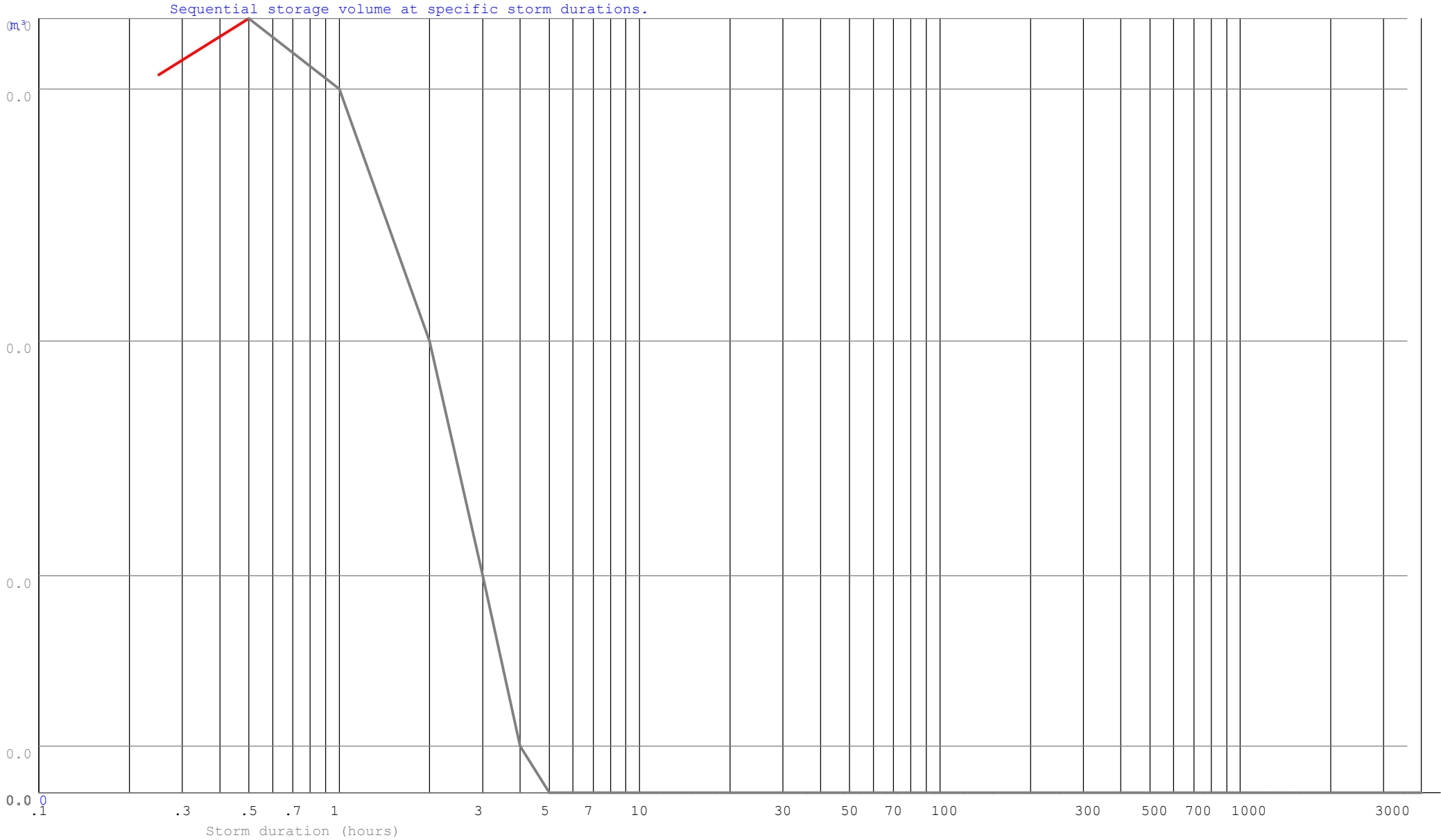
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Project **Land behind Sion Chapel, Pontfadog, LL20 7AS**

Title **1 in 2 Year (+40%) Attenuation Storage Calculations**





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Explanatory notes for Peak Flow Storage

- 1) This system uses the rainfall intensity/ duration curve calculated using either the Wallingford or FEH method as selected.
- 2) The balance is calculated from the inflow minus the outflow.
- 3) The storage volume is the maximum value of the balance curve.
- 4) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
- 5) References to 'storm duration' relate only to the hydrograph method (qv).
- 6) There are always 600 steps in the calculation process, thus a 'run' time of 10 hours will be sampled every minute,

Explanatory notes for Hydrograph Storage

- 1) The user has the choice of Summer or Winter curves
- 2) The mean intensity varies with the duration of the storm curve
- 3) There are always 120 steps in the calculation process, irrespective of storm duration.
- 4) The balance is calculated from the inflow minus the outflow.
- 5) The storage volume is the sum of the balance values for each step.
- 6) Varying durations should be tried to find the maximum storage value - this can be narrowed down very closely.

*Modelling using the flow characteristics of the restrictor is available using Vortex Control modelling function.
Please be aware that this function needs the full design data file to function.

Why do the two methods give different results?

The rainfall characteristics for each method are very different.

The Peak flow (using the Intensity/Duration/Frequency curve) does not model the actual rainfall. This curve is joined points which represent the mean intensity of a storm at a given duration i.e. a value of 19.5 mm/hr for a 60 minute storm indicates that over the sixty minute period, the mean intensity was 19.5 mm/hr. The calculation method samples the IDF curve for a given location and frequency (Return Period) and calculates the storage for that rate and duration less the outflow volume. The maximum value is displayed as the 'worst case' storage.

The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated from the IDF curve and applied to the curve data, calculating the storage for that step less the outflow volume. The final storage volume is the sum of the storage for all the steps.

It can be seen that these two methods are very different, and the user may have the choice of which result to use. This is not an exact science, though is often treated as such by those that do not understand the principles of the calculations.



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