Rear of Knowles Street, Penistone, Sheffield 6HB

NPPF: Flood Risk Assessment

For Mr R Bursztyn

KRS.0033.001.R.001.A

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Rear of Knowles Street, Penistone, Sheffield, S36 6HB	
Project	NPPF: Flood Risk Assessment
Client	Mr R Bursztyn
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EXECUTIVE SUMMARY

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

This FRA 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 the NPPF.

The development should not therefore be precluded on the grounds of flood risk.

The principal flood risk to the site is from tidal flooding from the Kirkwood Beck. In extreme events the Kirkwood Beck may overtop its banks and inundate the site with floodwater.

Flood risk to the site from the Kirkwood Beck can be considered to be limited, since Kirkwood Beck is located approximately 20m to the east of the site. Any overbank flow would follow the contours of the surrounding area and would flow directly to the north east rather than flowing west towards the site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the site are approximately 2m above the normal water level of the Kirkwood Beck.

The flood risk due to the Kirkwood Beck is of a minor nature with low water depths and velocities being experienced if the Kirkwood Beck was to overtop its banks.

The risk of flooding from fluvial flooding is considered to be of low significance. A number of secondary flooding sources have been identified which may pose a low significant risk to the site. These are:

- Surface Water Flooding
- Sewer Flooding

The flooding sources will only inundate the site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site.

The majority of the site is located within Flood Zone 1 and therefore has a 'low probability' of fluvial flooding, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%). However, a very small proportion (north eastern boundary) of the site is located within Flood Zone 2 and therefore has a 'medium probability' of flooding with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) in any year.

The proposed development is classified as 'more vulnerable', 'more vulnerable' uses are appropriate within Flood Zone 2 after the completion of a satisfactory FRA.

The site proposals are shown to pass the Sequential Test. The Exception Test will not need to be undertaken.

In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield surface water runoff rate of 0.38l/s or 3.83l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, 98.42m3 of storage will be incorporated into the site layout.

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located underground infiltration systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

The flood risk at the site will be reduced by property level protection measures. Measured used:

Property Layout - Sequential Approach: The sequential approach has been applied within the development site by locating the most vulnerable elements of the development in the lowest risk areas. The most vulnerable use, the dwelling, has been situated on the higher part of the site at a lower risk of flooding within Flood Zone 1, with the more flood-compatible uses such as the garden/landscaped areas being situated in the lower part of the site at a higher risk of flooding within Flood Zone 2.

Property Layout - Finished Floor/Threshold Level: Raising the finished floor and threshold levels of the dwelling should be used to mitigate the effects of flooding at the site. The finished floor and threshold levels of the dwelling will be located a minimum of 150mm above the existing ground levels at the site.

Property Layout – First Floor Accommodation: Accommodation is located on the first floor as well as the ground floor. This will allow residents to retreat to higher floor levels if needed.

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.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from properties can be easily and economically incorporated into the development of the site.

Safe Access and Egress Routes: Safe access and egress routes, including emergency access can be maintained for vehicles and/or by foot via Knowles Street.

This provides access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event.

Flood Warning: The property is located in a flood risk area therefore; the property will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

Flood Plan: A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause should be developed.

1.0 INTRODUCTION

1.1 Background

This Flood Risk Assessment (FRA) has been prepared by KRS Environmental Limited at the request of Mr R Bursztyn to support a planning application for the proposed development to the Rear of Knowles Street, Penistone, Sheffield, S36 6HB. This FRA includes an assessment of the existing and proposed surface water drainage of the site.

This FRA has been carried out in accordance with guidance contained in the National Planning Policy Framework (NPPF)[1] and associated Technical Guidance[2]. This FRA 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 National Planning Policy Framework (NPPF)

One of the key aims of the NPPF 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 FRA 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;
- if necessary provide the evidence to the LPA that the Sequential Test can be applied; and
- whether the development will be safe and pass part c) of the Exception Test if this is appropriate.

1.3 Report Structure

This FRA has the following report structure:

- Section 2 details the sources of information that have been consulted;

[1] Department for Communities and Local Government (2012) National Planning Policy Framework.
[2] Department for Communities and Local Government (2012) Technical Guidance to the National Planning Policy Framework.

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

2.0 SOURCES OF INFORMATION

2.1 Discussion with Regulators

Consultation and discussions with the relevant regulators have been undertaken during this FRA including the Environment Agency, the Local Planning Authority (LPA), and Sewerage Undertakers.

2.1.1 Environment Agency

The Flood and Water Management Act 2010 gives the Environment Agency a strategic overview role for all forms of flooding and coastal erosion. They also have direct responsibility for the prevention, mitigation and remediation of flood damage for main rivers and coastal areas. The Environment Agency is the statutory consultee with regards to flood risk and planning.

Environment Agency Flood Risk Standing Advice for England – National Version 2.0, the NPPF and Technical Guidance to the NPPF has been consulted and reviewed during this FRA. This has confirmed the level of FRA required and that a surface water drainage assessment is to be undertaken. Information regarding the current flood risk at the application site, local flood defences and flood water levels has been obtained from the Environment Agency.

Correspondence has been received from Cheryl Beech Customers and Engagement Officer at the Environment Agency (see Appendix 1).

2.1.2 Barnsley Council

Barnsley Council is the Local Planning Authority (LPA) and the Lead Local Flood Authority (LLFA) and has responsibilities for 'local flood risk', which includes surface runoff, groundwater and ordinary watercourses. Planning guidance written by Barnsley Council regarding flood risk was consulted to assess the mitigation policies in place.

The Barnsley Council Strategic Flood Risk Assessment (SFRA) and the Barnsley Council Preliminary Flood Risk Assessment (PFRA) which cover the site have been reviewed.

2.1.3 Yorkshire Water

Yorkshire Water is responsible for the disposal of waste water and supply of clean for this area. Information with regards to sewer and water main flooding contained within the Barnsley Council SFRA and the Barnsley Council PFRA have been consulted. All Water Companies have a statutory obligation to maintain a register of properties/areas which are at risk of flooding from the public sewerage system, and this is shown on the DG5 Flood Register.

3.0 LOCATION & DEVELOPMENT DESCRIPTION

3.1 Site Location

The site is located to the Rear of Knowles Street, Penistone, Sheffield, S36 6HB (see Drawing 1). The National Grid Reference (NGR) of the site is 425867,402893.

The site comprises a piece of land covering an area of approximately 0.3 hectares (ha) or 3000m^2.

3.2 Existing Development

The site currently comprises a greenfield development and is currently vacant land.

3.3 Proposed Development

It is understood that the proposals are for the erection of a residential dwelling (see Appendix 2).

Further details with regard to the proposed development can be found in the accompanying information submitted with the planning application.

3.4 Ground Levels

The minimum ground level is 204m above Ordnance Datum (mAOD) with a maximum ground level of 206mAOD.

3.5 Catchment Hydrology

The Kirkwood Beck is located approximately 20m to the east of the site and the River Don is located approximately 225m to the north east of the site (see Drawing 1). There are no other watercourses evident either on, or within the vicinity of the site.

3.6 Geology

The British Geological Survey (BGS) Map indicates that the bedrock underlying the site consists of the Penistone Flags – Sandstone. No superficial deposits underlay the site.

3.7 Groundwater

The Environment Agency has designated the bedrock deposits as Secondary A Aquifer- permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. No superficial aquifer is located at the site.

3.8 Source Protection Zone

The site is not located within an Environment Agency Source Protection Zone.

3.9 Soil

Information from the National Soil Resource Institute[3] details the site area as being situated on freely draining slightly acid loamy soils.

[3] https://www.landis.org.uk/soilscapes/

The Flood Studies Report WRAP soil map classification is type 3: i) relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England; ii) permeable soils with shallow ground water in low-lying areas; iii) mixed areas of permeable and impermeable soils, in approximately equal proportions.

3.10 Permeability / Infiltration Rate

In determining the future surface runoff from the site, the potential of using infiltration devices has been considered. As no site geotechnical information on the permeability and infiltration rate at the site has been acquired at this stage it is not possible to comment definitively upon the suitability of infiltration based systems. However, an overview of the general ground conditions (see Sections 3.6 to 3.9) may be used to gauge if there is potential for their application.

It has been concluded that there would be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales 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 FRA, but should be undertaken to inform the detailed drainage strategy for the site.

4.0 FLOOD RISK

4.1 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.

4.1.1 Fluvial (river) Flooding

Kirkwood Beck

The Kirkwood Beck is located approximately 20m to the east of the site (see Drawing 1) and therefore poses the principal flood risk to the site. In extreme events the Kirkwood Beck may overtop its banks and inundate the site with floodwater. Modelled water levels for the Kirkwood Beck are not available.

Flood risk to the site from the Kirkwood Beck can be considered to be limited, since Kirkwood Beck is located approximately 20m to the east of the site. Any overbank flow would follow the contours of the surrounding area and would flow directly to the north east rather than flowing west towards the site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the site are approximately 2m above the normal water level of the Kirkwood Beck.

The flood risk due to the Kirkwood Beck is of a minor nature with low water depths and velocities being experienced if the Kirkwood Beck was to overtop its banks.

Given the scale and nature of the proposed development and the size and location of the Kirkwood Beck it has been concluded that the Kirkwood Beck poses a low risk to the site. The risk from the Kirkwood Beck will be mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from the Kirkwood Beck is considered to be of **low significance**.

River Don

The River Don is located approximately 225m to the north east of the site (see Drawing 1). The River Don is designated as a 'Main River' and is therefore maintained by the Environment Agency.

Tables 1 shows the Environment Agency predicted water levels for the River Don adjacent to the site (see Appendix 1). The 1 in 25, 1 in 50, 1 in 75 year, 1 in 100 year, 1 in 200 year and 1 in 1000 year modelled water levels have been provided for the undefended scenario. Using the most conservative approach the modelled water levels from the node DON18_25782 has been used to assess the flood risk from River Don to the site.

Table 1 - River Don Modelled Water Levels (source Environment Agency)

Return Period (years)	Water Level (mAOD)
25	182.60
50	182.80
75	182.81
100	182.83
200	183.00
1000	183.53

The predicted water levels have been compared to the ground level of the site and areas within the vicinity of the site to assess the flood risk at the site in detail.

Water levels at this cross section have been modelled at 183.53mAOD during the 1 in 1000 event. Site ground levels are between 204mAOD and 206mAOD. Therefore, the site will not be inundated with floodwater from the River Don, there is a freeboard of over 20m above the 1 in 1000 year. Even with the effects of climate change over the lifetime of the development the site will not be inundated with floodwater from the River Don.

This has been confirmed within the Barnsley Council SFRA which shows that the site would not be inundated with floodwater from the River Don during the 1 in 100 year, in 100 year (plus climate change) and 1 in 1000 year events during overtopping of flood defences on the River Don.

Flood risk to the site from the River Don can be considered to be limited, since the River Don is located 225m to the north east of the site. Any overbank flow would follow the contours of the surrounding area and would flow directly to the east rather than flowing south towards the site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the site are approximately 20m above the normal water level of the River Don.

Therefore, it can be concluded that River Don does not pose a risk to the site. The risk from the River Don will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from the River Don is considered to be **not significant**.

4.1.2 Tidal (coastal) Flooding

The site is not located within the vicinity of tidal flooding sources and the risk of tidal flooding is considered to be **not significant**. Therefore, flooding from this source has not been considered further within this FRA.

4.1.3 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).

No below surface infrastructure and buildings are proposed for the site. Therefore, the risk of flooding from groundwater is considered to be **not significant**. Therefore, flooding from this source has not been considered further within this FRA.

4.1.4 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 site surroundings are relatively flat and there are no large catchments that would tend to generate surface water runoff towards the site. Surface water flow flooding tends to occur sporadically in both location and time such surface water flows would tend to be confined to the streets around the development.

The Barnsley Council SFRA shows that during the 1 in 100 year event flood depths of 0.15m to 0.30m would be experienced immediately adjacent to the Kirkwood Beck. The majority of the site would not be inundated with floodwater.

Therefore, the flood risk from surface water flooding is low. The risk from this source will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from surface water flooding is considered to be of **low significance**.

4.1.5 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.

It has been assumed that there are existing sewers located within the vicinity of the site and these will inevitably have a limited capacity so in extreme conditions there would be surcharges, which may in turn cause flooding. 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.

Given the design parameters normally used for drainage design in recent times and allowing for some deterioration in the performance of the installed systems, which are likely to have been in place for many years, an appropriate flood risk probability from this source could be assumed to have a return period in the order of 1 in 10 to 1 in 20 years. The provision of adequate level difference between the ground floors and adjacent ground level would reduce the annual probability of damage to property from this source to 1 in 100 years or less.

Sewer flooding poses a flood risk to the site however, the risk from this source will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0). Therefore, the risk of flooding from sewer flooding is considered to be of **low significance**.

4.1.6 Flooding from Artifical Drainage Systems/Infrastructure Failure

There are no other nearby artificial water bodies, reservoirs, water channels and artificial drainage systems that could be considered a flood risk to the site. Drawing 2 shows that the site is not at risk of flooding from reservoir failure.

The risk of flooding from artifical drainage systems/infrastructure failure is considered to be **not significant.** Therefore, flooding from these sources has not been considered further within this FRA.

4.2 Environment Agency Flood Zones

A review of the Environment Agency's Flood Zones indicates that the majority of the site is located within Flood Zone 1 and therefore has a 'low probability' of fluvial flooding as shown in Drawing 3, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%).

However, a very small proportion (north eastern boundary) of the site is located within Flood Zone 2 and therefore has a 'medium probability' of flooding with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) in any year.

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 Environment Agency Flood Zones and acceptable development types are explained in Table 2. Table 2 (highlighted in green), shows some development types are generally acceptable in Flood Zone 2.

In the Technical Guidance to the NPPF (Table 1) appropriate uses have been identified for the Flood Zones. Applying the Flood Risk Vulnerability Classification in Table 2 and 3 of the Technical Guidance to the NPPF, the proposed development is classified as 'more vulnerable'.

Table 3 of this report and Table 3 of the Technical Guidance to the NPPF state that 'more vulnerable' uses are appropriate within Flood Zone 2 after the completion of a satisfactory FRA.

Table 2 - Environment Agency 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

Table 3 - Flood Risk Vulnerability and Flood Zone 'Compatibility' as identified in Table 3 of the Technical Guidance to the NPPF

Flood Risk Vulnerability classification(see Table 1 of the Technical Guidance to the NPPF)	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	Yes	✓	✓
Zone 2	✓	✓	Exception test required	✓	✓
Zone 3a	Exception test required	✓	×	Exception test required	✓
Zone 3b 'Functional Floodplain'	Exception test required	✓	×	×	×

Key:

✓: Development is appropriate, ×: Development should not be permitted.

4.2 Historic Flooding

The Environment Agency has confirmed that a proportion of the site flooded in 2007 (see Appendix 1). This record does not give an indication of the depth of flooding on the site. The return period of the event is also unknown. However, the site did not flood during the 1947, 1982 or 2000 flood events.

Data from the BGS indicates that the types of deposits in the locality of the site are of the type normally associated with floodplains. This normally relates to flooding which happened many thousands of years ago. This data should only be considered as complementary to the Environment Agency's Flood Map. This BGS data does not indicate the likelihood of flooding, since such deposits may be due to flood events which occurred thousands of years ago. It was produced by characterising Superficial (Drift) Deposits in terms of their likely vulnerability to flooding, either from coastal or inland water flow and reflects areas which may have flooded in the recent geological past.

There are no records of anecdotal information of flooding at the site. The British Hydrological Society "Chronology of British Hydrological Event[4]" has no information on flooding within the vicinity of the site. No other historical records of flooding for the site have been recorded.

4.3 Existing and Planned Flood Defence Measures

The Environment Agency has confirmed that there are no formal flood defences within this area (see Appendix 1 and Drawing 3).

Further property level protection measures will be used to protect the site from flooding these are discussed in Section 7.0.

4.4 Site Specific Flood Risk 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.

[4] http://www.dundee.ac.uk/geography/cbhe/

Table 4 - Risk Posed by Flooding Sources

Sources of Flooding	Potential Flood Risk	Potential Source	Probability/Significance
Fluvial Flooding	Yes	Kirkwood Beck	Low
Tidal Flooding	No	None Reported	None
Groundwater Flooding	No	None Reported	None
Surface Water Flooding	Yes	Poor Permeability	Low
Sewer Flooding	Yes	Local Sewers	Low
Flooding from Artificial Drainage Systems/Infrastructure Failure	No	None Reported	None

The principal flood risk to the site is from fluvial flooding from the Kirkwood Beck. In extreme events the Kirkwood Beck may overtop its banks and inundate the site with floodwater.

Flood risk to the site from the Kirkwood Beck can be considered to be limited, since Kirkwood Beck is located approximately 20m to the east of the site. Any overbank flow would follow the contours of the surrounding area and would flow directly to the north east rather than flowing west towards the site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the site are approximately 2m above the normal water level of the Kirkwood Beck.

The flood risk due to the Kirkwood Beck is of a minor nature with low water depths and velocities being experienced if the Kirkwood Beck was to overtop its banks. The risk of flooding from fluvial flooding is considered to be of **low significance.** A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

- Surface Water Flooding
- Sewer Flooding

The flooding sources will only inundate the site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0).

As noted in Section 4.2, the majority of the site is located within Flood Zone 1 and therefore has a 'low probability' of fluvial flooding, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%). However, a very small proportion (north eastern boundary) of the site is located within Flood Zone 2 and therefore has a 'medium probability' of flooding with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) in any year.

The proposed development is classified as 'more vulnerable', 'more vulnerable' uses are appropriate within Flood Zone 2 after the completion of a satisfactory FRA.

The site is unlikely to flood except in extreme conditions.

5.0 SEQUENTIAL APPROACH

5.1 Sequential Test

The risk-based Sequential Test in accordance with the NPPF aims to steer new development to areas at the lowest probability of flooding (i.e. Flood Zone 1).

The majority of the site is located within Flood Zone 1 and therefore has a 'low probability' of fluvial flooding as shown in Drawing 3, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%). However, a very small proportion (north eastern boundary) of the site is located within Flood Zone 2 and therefore has a 'medium probability' of flooding with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) in any year.

However, where an individual proposes to develop a site in an existing flood risk area the consideration of alternative sites is not likely to be a realistic option.

This planning application is for the development of a residential development in a flood risk area. This is the only site in the ownership of the client and therefore the only site available to them to develop. There are no alternative sites available to develop.

The wider area surrounding the proposed development site is affected by a very similar, and in many cases, higher risk of flooding due to generally flat topography.

Also the only viable use of the site would be 'highly vulnerable' or 'more vulnerable' such as residential purposes. The 'less vulnerable' uses identified within the NPPF includes 'general industrial, employment, commercial & retail development, transport & utilities infrastructure, car parks, mineral extraction site and associated processing facilities, excluding waste disposal sites'.

Therefore, the only viable use of the premises would be one which falls within the category 'highly vulnerable' or 'more vulnerable' uses for residential purposes.

Environment Agency guidance on the sequential test suggests that the test should also be applied at site level and that the detailed layout takes account of any differences in risk across the site.

The sequential approach has been applied within the development site by locating the most vulnerable elements of the development in the lowest risk areas. The most vulnerable use, the dwelling, has been situated on the higher part of the site at a lower risk of flooding within Flood Zone 1, with the more flood-compatible uses such as the garden/landscaped areas being situated in the lower part of the site at a higher risk of flooding within Flood Zone 2.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site (see Section 7.0).

5.2 Exception Test

Applications for 'more vulnerable' uses located within Flood Zone 2 are not subject to the Exception Test as confirmed within Table 3 of this report and Table 3 of the Technical Guidance to the NPPF.

6.0 SURFACE WATER DRAINAGE

6.1 Surface Water

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 surface water management 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 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 and the soon to be released National Sustainable Drainage Systems (SUDS) Standards.

6.2 Discharge of Surface Water

There are three possible options to discharge the surface water runoff in accordance with requirement H3 of the Building Regulations 2002, this hierarchy is also promoted within the NPPF. 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. The design should seek to improve the local runoff profile by using systems that can either attenuate runoff and reduce peak flow rates or positively impact on the existing surface water runoff.

6.2.1 Soakaway/Infiltration System

It has been concluded that there would be infiltration drainage within the soils and bedrock at the site. SUDS methods such as soakaways, permeable pavements, grassed swales should work at the site.

6.2.2 Watercourse

The Kirkwood Beck is located approximately 20m to the east of the site (see Drawing 1). Therefore, it will be possible to discharge surface water runoff from the site into this watercourse.

6.2.3 Sewer

It has been assumed that there are existing public sewers near to the site within Knowles Street. It should be confirmed with Yorkshire Water if they have the capacity to accept any discharge of surface water from the site. If so, it may be possible to discharge to the public sewers after attenuating the surface water on site as a secondary option.

6.3 Surface Water Runoff Rates

The site currently comprises a greenfield development and is currently vacant land. The site comprises a piece of land covering an area of approximately 0.30 hectares (ha) or 3000m^2.

It is understood that the existing drainage infrastructure at the site efficiently and effectively manages surface water runoff generated at the site. As there is no history of surface water flooding at the site it is likely that the current drainage system is sufficient for the current site use.

The planning application is for a residential dwelling (see Appendix 2). The incorporation of a garden and landscaped areas will allow a proportion of the rainfall to infiltrate into the soil substrate.

Table 5 shows that the existing site is constructed from 0.30ha (100%) of permeable surfaces with no impermeable surfaces located on the site. The proposed development will increase the impermeable area to 0.15ha (50%) generating higher surface water runoff post-development. If uncontrolled, this could in turn increase the risk of flooding to the site and off-site locations.

Table 5 - Site Areas

Element	Pre-development	Post-development	Difference
Permeable Surfaces (ha)	0.30 (3000m^2)	0.15 (1500m^2)	- 0.15 (1500m^2)
Impermeable Surfaces (ha)	0.15 (1500m^2)	0.15 (1500m^2)	+ 0.15 (1500m^2))
Total (ha)	**0.30 (3000m^2)**	**0.30 (3000m^2)**	-----

In order to quantify any potential increase in surface water runoff, the pre- and post-development runoff rates from the site must be determined. The rates of runoff have been determined using the current 'industry best practice' guidelines as outlined in the Interim Code of Practice for SUDS[5]. The recommended methodology for sites up to 50 hectares in area is the Institute of Hydrology Report 124 method (IoH124)[6].

The following parameters have been incorporated into the runoff calculations within the Masterdrain Drainage Software:

- Catchment Area: 0.11ha;
- M5-60 (mm): 18.9;
- R = 0.36;
- Soil Runoff: 0.40;
- SAAR: 775;
- Hydrological Area: 3;
- Hydrological Zone: 8;
- Soil Classification for WRAP Type: 3
- Urbanisation:
  - Pre-development = 0%
  - Post-development = 50%

[5] Office of the Deputy Prime Minister, National SUDS Working Group, July 2004, Interim Code of Practice for sustainable drainage systems.
[6] Institute of Hydrology (1994) Flood estimation for small catchments. Report no 124.

Table 6 below shows a comparison of surface water runoff rates pre- (see Appendix 3) and post-development (see Appendix 4) and indicates that the proposed development would result in an increase in the 1 in 100 year (plus climate change) peak runoff by 1.15l/s or 11.51l/s/ha if the surface water runoff from the developed site is not attenuated.

The greenfield runoff rate has been calculated using the method described in IoH 124. QBAR (rural) has been calculated to be 0.38l/s or 3.83l/s/ha.

Table 6 - Pre-development and Post-development Peak Flows

Return Period (years)	Pre-development		Post-development		Difference	
	l/s	l/s/ha	l/s	l/s/ha	l/s	l/s/ha
1	0.33	3.26	0.71	7.14	+ 0.38	+ 3.88
2	0.38	3.83	0.84	8.40	+ 0.46	+ 4.57
30	0.64	6.44	1.41	14.11	+ 0.77	+ 7.67
100	0.80	8.05	1.76	17.64	+ 0.96	+ 9.59
100 + cc	0.96	9.66	2.11	21.17	+ 1.15	+ 11.51

Note:

20% added to the data to account for long-term climate change as stated in the NPPF. The 1 year, 30 year and 100 year annual probability events are of importance to the NPPF, Water Companies and the Environment Agency when looking at surface water discharge and flood risk.

6.4 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 the NPPF 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 of NPPF that these are considered as the primary means of collection, control and disposal for storm water as close to source as possible.

Table 7 shows the volume of storage required for the proposed development estimated using the Masterdrain Drainage Software for the 1, 30 and 100 year events, with a 30% allowance for climate change (increase in peak rainfall) assuming the proposed 50% impermeable area with the greenfield runoff rate of 0.38l/s or 3.83l/s/ha used as the limiting discharge rate (see Appendix 5).

Table 7 - Storage Volume

Return Period (years)	Limiting Discharge Rate (l/s)	Volume (m^3)
1 + 30%	0.38l/s or 3.83l/s/ha	27.50
30 + 30%		71.92
100 + 30%		98.42

This volume may be reduced by implementing a complex control at the outfall which would increase the rate of discharge from the site for events above the 1 in 30 year event. This should be explored at detailed design stage and agreed with the LPA and Environment Agency.

This volume of attenuation storage could be provided by a variety of means these are discussed below.

6.5 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 identified[7]:

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.

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[8] 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 Environment Agency guidance applies a sustainability hierarchy to the various types of SUDS systems, this is summarised in Table 8.

[7] CIRIA (2004) Report C609, Sustainable Drainage Systems – Hydraulic, Structural and Water Quality advice.
[8] CIRIA C697 SUDS Manual, 2007.

Table 8 - Sustainability Hierarchy

Most 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	✓	✓	
↓ Least Sustainable	**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 (Table 5.6) identifies the number of treatment trains or SUDS devices through which flow should pass from various point sources of runoff (see Table 9). 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.

Table 9 - 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

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.

6.5.1 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.

It has been concluded that soakaways will work at the site and can be used to attenuate the surface water runoff.

(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. It is also possible to provide plot-by-plot systems connecting in to a site wide system. There may be scope to apply these features on a plot-by-plot basis as the layout develops further.

These systems also encourage biological treatment of flow and extraction of oils and heavy metals from the run-off.

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 has been concluded that permeable paving will work at the site and can be used to attenuate the surface water runoff.

(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.

(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 25-125 mm 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.

As the buildings will not have flat roofs and the application of green roofs in a domestic scenario is limited due to on-going maintenance and access requirements of any system therefore, this is not a practical option and is therefore not considered further.

6.5.2 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.

It has been concluded that infiltration trenches will work at the site and can be used to attenuate the surface water runoff.

(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.

It has been concluded that swales will work at the site and can be used to attenuate the surface water runoff.

(iii) Filter Strips

Filter strips will be smaller in plan area than a swale although the swale can be landscaped to be incorporated in to the verge of the carriageway, combining two functions. There is space available on this site to provide a length of swale and it is likely that these will provide a suitable means of surface water disposal.

It has been concluded that filter strips will work at the site and can be used to attenuate the surface water runoff.

6.5.3 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.

In this case, the small size of the site would not permit the use of these systems.

(ii) 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 (>$200m^3$) 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.

(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 <$200m^3$ 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.

This option could be used in combination with other SUDS elements to provide the required storage volume.

(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.

(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.

As the site is relatively sloping, the safe management of flows on the surface and the mobilisation of sufficient attenuation volumes will be very difficult. It is therefore recommended that these systems are only used in emergency circumstances.

6.6 Proposed Surface Water Management Strategy (SWMS)

The objective of this SWMS is to ensure that a sustainable drainage solution can be achieved which reduces the peak discharge rate to the greenfield runoff rate to manage and reduce the flood risk posed by the surface water runoff from the site.

For all development, both the Building Regulations and the NPPF promote a hierarchical approach to surface water management (see Section 6.2). This approach has been adopted within this SWMS with infiltration being utilised wherever possible, if infiltration is not possible, discharge will be to the Kirkwood Beck to the east of the site.

In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield surface water runoff rate of 0.38l/s or 3.83l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, $98.42m^3$ of storage will be incorporated into the site layout (see Table 7).

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located underground infiltration systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

One treatment train will be used on this site, to ensure that the receiving environments are not put at risk of pollution by new developments.

The remainder of the site that is not formally drained, i.e. gardens and areas of open space, 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.

These methods will reduce peak flows, the volume of runoff, and slow down flows and will provide a suitable SUDS solution for this site.

These preliminary considerations are based on the outline development scheme provided and hence the design purposes.

The adoption of a surface water management 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.

Where SUDS are to be used it must be established that these options are feasible, can be adopted and properly maintained and would not lead to any other environmental problems with a maintenance schedule or the lifetime of the facility and these issues should be considered at the detailed design stage.

At this stage of the planning process it is proposed that a planning condition can be adopted to cover the detailed design of the surface water runoff from the site. It is proposed that the detailed drainage design of the final scheme would be secured by a planning condition attached to any planning permission granted and agreed with the Environment Agency, Yorkshire Water and the LPA prior to works commencing.

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.

6.7 Designing for Local Drainage System Failure

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[9].

The attenuation requirements have been designed to accommodate the 100 year storm event plus climate change (+ 30%). To prevent flooding of the proposed properties if the design event is exceeded the surface flows generated will be managed.

The design of the site layout provides an opportunity to manage this 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 public sewers located within the vicinity of the site. An exceedance or blockage event of the sewers would not affect the proposed property because finished floor levels will be a minimum of 600mm above surrounding ground levels, ensuring any exceedance flooding would not affect the building. Exceedance flows would be contained within Knowles Street.

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.

Therefore, managing and mitigating 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.

[9] CIRIA (2006) Designing for exceedance in urban drainage – good practice.

7.0 RISK MANAGEMENT

7.1 Introduction

The flood risk at this location is considered suitable for 'less vulnerable' developments within the NPPF. 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 property level protection measures (see Table 10); these are discussed in more detail below.

Table 10 - Property Level Protection Measures

Measure	Details	Description
Property Layout	1. Sequential Approach 2. Finished Floor/Threshold Levels 3. First Floor Accommodation	Prevents water ingress and reduce vulnerability of occupants to flooding
Flood Resistance/ Flood Resilience	1. Raising utility entry points 2. Using first floor or ceiling down electrical circuits 3. Sloping landscaping away from properties	Prevents water ingress
Safe Access and Egress Routes	1. Safe access and escape route to areas outside of floodplain	Reduce vulnerability of occupants to flooding
Flood Warning	1. Warning so the property can be safely evacuated and mitigation measures to be put in place	Reduce vulnerability of occupants to flooding
Flood Plan	1. Outlines precautions and actions taken when a flood event is anticipated	Reduce vulnerability of occupants to flooding and makes them aware of the mechanisms of flooding at the site

7.2 Property Layout

7.2.1 Sequential Approach

The sequential approach has been applied within the development site by locating the most vulnerable elements of a development in the lowest risk areas. The most vulnerable use, the dwelling, has been situated on the higher part of the site at a lower risk of flooding with the more flood-compatible uses such as the garden/landscaped areas being situated in the lower part of the site at a higher risk of flooding.

The most vulnerable use, the dwelling, has been situated on the higher part of the site at a lower risk of flooding within Flood Zone 1, with the more flood-compatible uses such as the garden/landscaped areas being situated in the lower part of the site at a higher risk of flooding within Flood Zone 2.

7.2.2 Finished Floor/Threshold Level

Raising the finished floor and threshold levels of the dwelling should be used to mitigate the effects of flooding at the site.

The finished floor and threshold levels of the dwelling will be located a minimum of 150mm above the existing ground levels at the site.

7.2.3 First Floor Accommodation

Accommodation is located on the first floor as well as the ground floor. This will allow residents to retreat to higher floor levels if needed.

7.3 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.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from properties can be easily and economically incorporated into the development of the site.

7.4 Safe Access and Egress Routes

The NPPF requires that, where required, safe access and escape is available to/from new developments in flood risk areas. Access routes should be such that occupants can safely access and exit their dwellings in design flood conditions. These routes must also provide the emergency services with access to the development during a flood event and enable flood defence authorities to carry out any necessary duties during the period of flood.

Safe access and egress routes, including emergency access can be maintained for vehicles and/or by foot via Knowles Street.

This provides access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event.

7.5 Flood Warning

The property is located in a flood risk area therefore; the property will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

7.6 Flood Plan

A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause should be developed (see http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx). Sensible precautions would include raising electrical items, irreplaceable items and sentimental items off the ground or where possible moving them to a higher floor, rolling up carpets and rugs and turning off utilities. In addition, consider what actions you would take should the property need to be evacuated including access and egress routes and preparing a flood kit in advance containing warm clothing, medication, a torch, food and wellingtons.

The Flood Plan is a ‘living’ document and therefore should be periodically reviewed and updated to provide advice and guidance to occupants in the event of an extreme flood.

The Flood Plan will therefore reduce the vulnerability of the occupants to flooding and makes them aware of the mechanisms of flooding at the property.

7.7 Flooding Consequences

The mitigation measures detailed above show that the flood risk can be effectively managed and therefore the consequences of flooding are acceptable.

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

8.0 SUMMARY AND CONCLUSIONS

8.1 Introduction

This report presents a FRA in accordance with the NPPF for the proposed development to the Rear of Knowles Street, Penistone, Sheffield, S36 6HB.

This FRA 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.

8.2 Flood Risk

The principal flood risk to the site is from tidal flooding from the Kirkwood Beck. In extreme events the Kirkwood Beck may overtop its banks and inundate the site with floodwater.

Flood risk to the site from the Kirkwood Beck can be considered to be limited, since Kirkwood Beck is located approximately 20m to the east of the site. Any overbank flow would follow the contours of the surrounding area and would flow directly to the north east rather than flowing west towards the site. The flood risk can also be considered to be limited due to the difference in elevations. The ground levels of the site are approximately 2m above the normal water level of the Kirkwood Beck.

The flood risk due to the Kirkwood Beck is of a minor nature with low water depths and velocities being experienced if the Kirkwood Beck was to overtop its banks.

The risk of flooding from fluvial flooding is considered to be of **low significance**. A number of secondary flooding sources have been identified which may pose a **low significant** risk to the site. These are:

- Surface Water Flooding
- Sewer Flooding

The flooding sources will only inundate the site to a relatively low water depth and water velocity, will only last a short period of time, in very extreme cases and will not have an impact on the whole of the proposed development site.

The flood risk at the site will be further mitigated by using a number of property level protection measures to manage and reduce the overall flood risk at the site.

The majority of the site is located within Flood Zone 1 and therefore has a ‘low probability’ of fluvial flooding, with less than 1 in 1000 annual probability of river flooding in any year (<0.1%). However, a very small proportion (north eastern boundary) of the site is located within Flood Zone 2 and therefore has a ‘medium probability’ of flooding with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) in any year.

The proposed development is classified as ‘more vulnerable’, ‘more vulnerable’ uses are appropriate within Flood Zone 2 after the completion of a satisfactory FRA.

The site is unlikely to flood except in extreme conditions.

8.3 Sequential Approach

The site proposals are shown to pass the Sequential Test. The Exception Test will not need to be undertaken.

8.4 Surface Water Drainage

The objective of the SWMS is to ensure that a sustainable drainage solution can be achieved which reduces the peak discharge rate to the greenfield runoff rate to manage and reduce the flood risk posed by the surface water runoff from the site.

In order to limit the rate and volume of surface water runoff that is discharged, it will be necessary to include a flow control device. The surface water runoff from the site will be attenuated to the greenfield surface water runoff rate of 0.38l/s or 3.83l/s/ha for all events up to and including the 1 in 100 year (+ 30%) rainfall event.

As a consequence of limiting the rate of discharge from the site to the greenfield runoff rate, at times of heavy rainfall the volume of water leaving the site will be significantly less than that draining from it. In order to prevent this water backing up in the system and causing flooding, 98.42m3 of storage will be incorporated into the site layout.

The size of this storage has been calculated such that the proposed development has the capacity to accommodate the 100 year rainfall event including a 30% increase in rainfall intensity that is predicted to occur as a result of climate change. At this stage it is anticipated that the attenuation storage will be located underground infiltration systems such as: soakaways, filter strips, swales, infiltration trenches, permeable paving, and cellular storage.

8.5 Risk Management

The flood risk at the site will be reduced by property level protection measures. Measured used:

Property Layout - Sequential Approach: The sequential approach has been applied within the development site by locating the most vulnerable elements of the development in the lowest risk areas. The most vulnerable use, the dwelling, has been situated on the higher part of the site at a lower risk of flooding within Flood Zone 1, with the more flood-compatible uses such as the garden/landscaped areas being situated in the lower part of the site at a higher risk of flooding within Flood Zone 2.

Property Layout - Finished Floor/Threshold Level: Raising the finished floor and threshold levels of the dwelling should be used to mitigate the effects of flooding at the site. The finished floor and threshold levels of the dwelling will be located a minimum of 150mm above the existing ground levels at the site.

Property Layout – First Floor Accommodation: Accommodation is located on the first floor as well as the ground floor. This will allow residents to retreat to higher floor levels if needed.

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.

Relatively simple measures such as raising utility entry points, using first floor or ceiling down electrical circuits and sloping landscaping away from properties can be easily and economically incorporated into the development of the site.

Safe Access and Egress Routes: Safe access and egress routes, including emergency access can be maintained for vehicles and/or by foot via Knowles Street.

This provides access to areas located outside of the floodplain where facilities such as community centres, shops etc. are located which may be used in the event of a flood event.

Flood Warning: The property is located in a flood risk area therefore; the property will participate in the Environment Agency flood warning telephone service. The Environment Agency operate a free flood warning service providing alerts by phone, text or email when flooding is anticipated providing an opportunity for home owners to take necessary precautions, giving enough time for the property to be safely evacuated and mitigation measures to be put in place.

Flood Plan: A Flood Plan outlining the precautions and actions you should take when a flood event is anticipated to help reduce the impact and damage flooding may cause should be developed.

8.6 Conclusion

The site is unlikely to flood except in extreme conditions. This takes into account the property level protection measures.

Table 11 summarises the probability and consequence of flooding for the site with and without mitigation measures.

This FRA 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 the NPPF.

The development should not therefore be precluded on the grounds of flood risk.

Table 11 - Probability and Consequences of all Sources of Flooding

Sources of Flooding	Potential Source	Probability	Consequence & Impact Without Mitigation	Consequence & Impact With Mitigation	Comment
Fluvial Flooding	Kirkwood Beck	Low	Low	Low	Mitigation measures used
Tidal Flooding	None Reported	None	Negligible	Negligible	None
Groundwater Flooding	None Reported	None	Negligible	Negligible	Mitigation measures used
Surface Water Flooding	Poor Permeability	Low	Low	Low	Mitigation measures used
Sewer Flooding	Local Sewers	Low	Low	Low	Mitigation measures used
Flooding from Artificial Drainage Systems/Infrastructure Failure	None Reported	None	Negligible	Negligible	None

DRAWINGS

DRAWING 1 – Site Location

KEY

Site Boundary

KRS Environmental

PROJECT

Rear of Knowles Street, Penistone, Sheffield

CLIENT

Mr R Bursztyn

TITLE

Site Location

PROJECT REF

KRS.0033.001

DRAWING NO

1

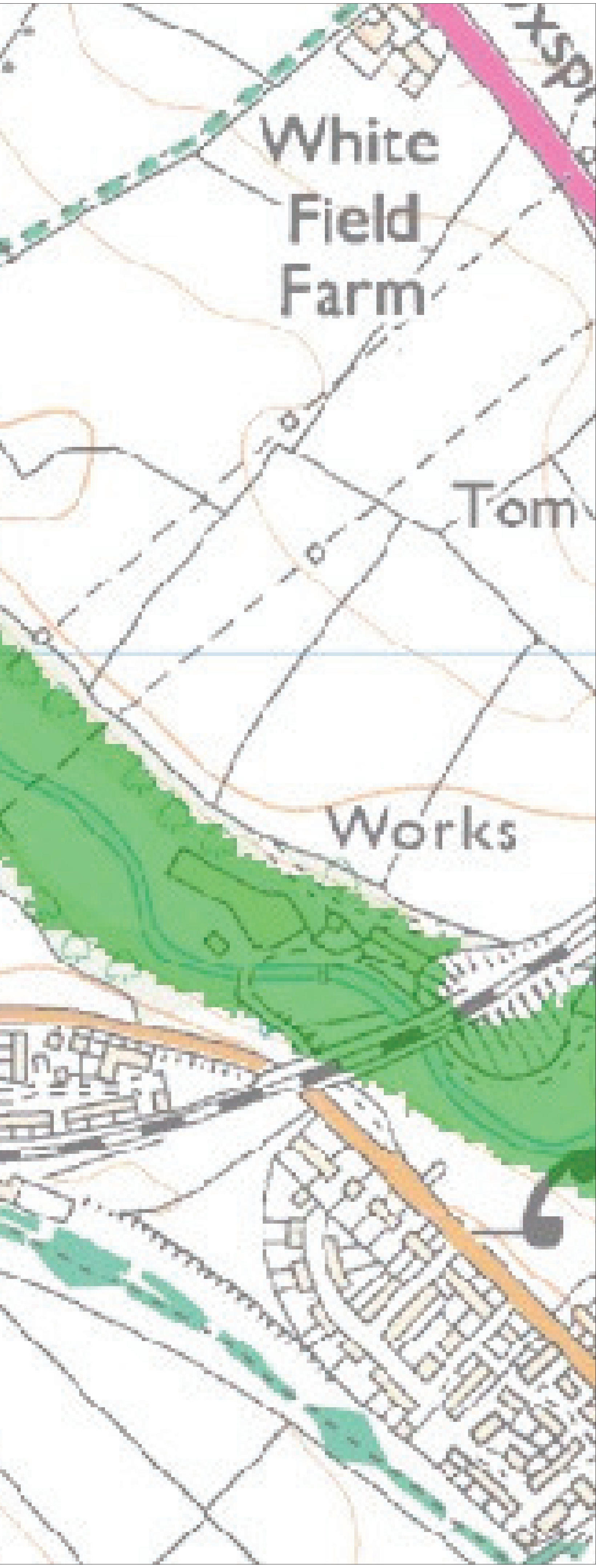
SCALE

NTS@A3

DATE

October 2013

DRAWING 2 – Environment Agency Reservoir Flood Map



KEY

Site Boundary

Reservoir Flood Outline

PROJECT

Rear of Knowles Street, Penistone, Sheffield

CLIENT

Mr R Bursztyn

TITLE

Environment Agency Reservoir Flood Map

PROJECT REF

KRS.0033.001

DRAWING NO

2

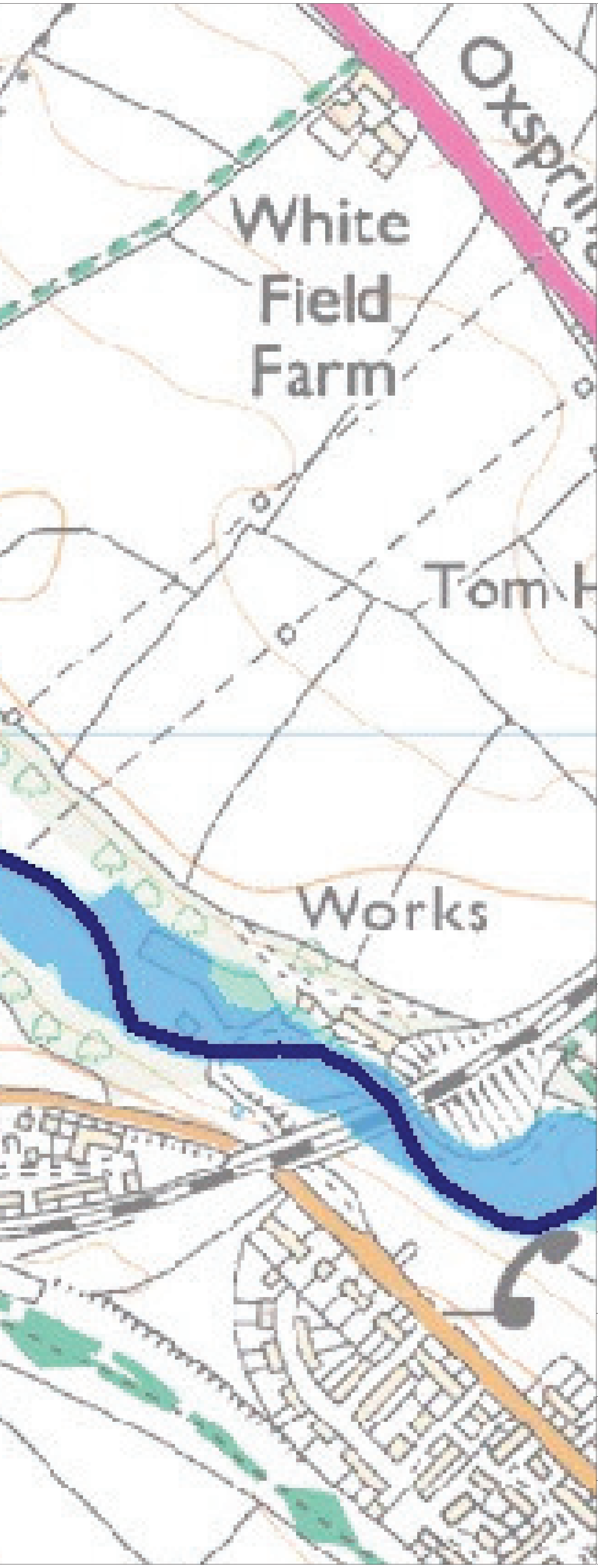
SCALE

NTS@A3

DATE

October 2013

DRAWING 3 – Environment Agency Flood Zones



KEY

- Site Boundary
- Flood Zone 3
- Flood Zone 2
- Flood Zone 1

KRS Environmental

PROJECT	Rear of Knowles Street, Penistone, Sheffield
CLIENT	Mr R Bursztyn
TITLE	Environment Agency Flood Zones
PROJECT REF	KRS.0033.001
DRAWING NO	3
SCALE	NTS@A3
DATE	October 2013

APPENDICES

APPENDIX 1 – Environment Agency Correspondence

keelan serjeant

From: Beech, Cheryl <Cheryl.Beech@environment-agency.gov.uk>
Sent: 09 October 2013 14:24
To: keelan serjeant
Subject: Your Enquiry: RFI/2013/27158
Attachments: Standard_Notice sept 2012.pdf; VAT Receipt.pdf; Flood History Map.pdf; Flood Map.pdf; Model Results - Undefended.pdf; Node Point Location Map.pdf

Our Ref: RFI/2013/27158

Your Ref:

Dear Keelan

Provision of Product 4 for Knowles Street, Penistone, Sheffield S36 6HB

Thank you for your request of 18 September 2013 to use Environment Agency data, Product 4, in the development of the above site. The information is attached.

If you have requested this information to help inform a development proposal, then you should note the detail in the attached advisory text on the use of Environment Agency Information for Flood Risk Assessments.

Supporting Information

The Flood Map

Please find enclosed extract from the Flood Map.

The Flood Map provides information on flooding from rivers and the sea for England and Wales. The Flood Map also has information on flood defences and the areas benefiting from those flood defences.

The Flood Map shows the following:

1. Flood Zone 3 (dark blue area on the enclosed map): natural flood plain area that could be affected by flooding from rivers and/or the sea – not taking into account the presence of any flood defences

- For flooding from rivers the map indicates the extent of a flood with a 1% (1 in 100) chance of happening each year;
- For flooding from the sea the map shows the extent of a flood with a 0.5% (1 in 200) chance of happening each year.

2. Flood Zone 2 (light blue area): natural flood plain area that could be affected by flooding from rivers and/or the sea – not taking into account the presence of any flood defences. Flood Zone 2:

- indicates the extent of a flood with a 0.1% (1 in 1000) chance of happening each year.
- and/or indicates the greatest recorded historic flood, whichever is greater.

3. Flood defences built in the last five years to protect against river floods with a 1% (1 in 100) chance of happening each year, together with some natural or constructed entities which retain, store or channel water and which may protect against smaller floods.

4. Areas benefiting from flood defences - areas that benefit from the flood defences shown, in the event of a river flood with a 1% (1 in 100) chance of happening each year, or a flood from the sea with a 0.5% (1 in 200) chance of happening each year. If the defences were not there, these areas would flood.

Flood History

See the attached map showing the flood history for this site. The extent of flooding, and/or flood level information is only shown for those watercourses surveyed after the flood. Other flooding may have occurred which is not shown. This is the best information currently available.

Water causing flooding can come from different places, for example from rivers or the sea; surface water (i.e. rainwater flowing over or accumulating on the ground before it is able to enter rivers or the drainage system); overflowing or backing up of sewers or drainage systems which have been overwhelmed or from groundwater rising up from underground aquifers.

Currently the Environment Agency can only supply flood risk data relating to the risk of flooding from rivers or the sea. However you should be aware that in recent years, there has been an increase in flood damage caused by surface water flooding or drainage systems that have been overwhelmed. Local Authorities and/or Water Companies may be able to provide some knowledge on the risk of flooding from sources other than rivers and the sea and we are working with these organisations to improve knowledge and understanding of surface water flooding.

Assets

There are no flood defences helping to reduce flood risk in your area of interest.

Modelling - 2012 Sheffield Comprehensive Flood Review Model

Modelled flood levels are available.

Please see enclosed:

- Table of results for peak water levels for the 0.1% (1 in 1000yr), 0.5% (1 in 200yr) 1% (1 in 100yr), 1.3% (1 in 75yr), 2% (1 in 50yr), 4% (1 in 25yr).
- and a map showing the location of the model node points

Please see on the attached flood map the updated flood zones from this study. These will be officially be published in August 2013.

Please note that we are currently completing the climate change scenario for this model. Please contact us later on in the year if you would like an update on this study.

Climate Change

See attached extract from the National Planning Policy Framework Technical Guidance by Communities and Local Government.

Flood Warning

The site is covered by a Flood Warning. To register to receive this service, you can call Floodline 24 hours a day on 0845 988 1188.

LIDAR Data

Light Detection and Ranging (LIDAR) is an airborne mapping technique, which uses a laser to measure the distance between the aircraft and the ground. This technique results in the production of an accurate, cost-effective terrain model suitable for assessing flood risk and other environmental applications.

The Environment Agency owns two LIDAR systems, which are installed in a survey aircraft along with its other operational remote sensing instruments.

The aircraft is positioned and navigated using Global Positioning System (GPS) corrected to known ground reference points. The aircraft typically flies at a height of about 800 metres above ground level and a scanning mirror allows a swath width of about 600 metres to be surveyed during a flight.

To get a license for the data you will need to contact our Science Group, stating the area you are interested in (preferably an OS Grid Reference, or a map with the area outlined). There may be a charge for this data.

Low resolution Data is returned as an ASCII grid, which can easily be converted to a surface model for use in most GIS applications, and is provided in 2km x 2km tiles, at a resolution of 2m.

High resolution Data is also returned as an ASCII grid, in 0.5km x 0.5km tiles, at a resolution between 0.125 and 0.5m.

For current catalogue of coverage see: http://www.geomatics-group.co.uk/GeoCMS/order.aspx

To obtain the data and license agreement, please contact:

Environment Agency Geomatics
Phoenix House
Lower Bristol Road
Bath BA2 9ES
Tel: 01225 487658
Fax: 01225 487643
E-mail: archived-lidardata@environment-agency.gov.uk
Or visit the website at www.geomatics-group.co.uk

This information is provided subject to the attached notice which we advise that you should read.

We would be really grateful if you could spare five minutes to help us improve our service. Please click on the link below and fill in our survey – we use every piece of feedback we receive:

http://www.surveyshack.com/link/a3d10

If you require any further help, please do not hesitate to contact me.

Yours sincerely

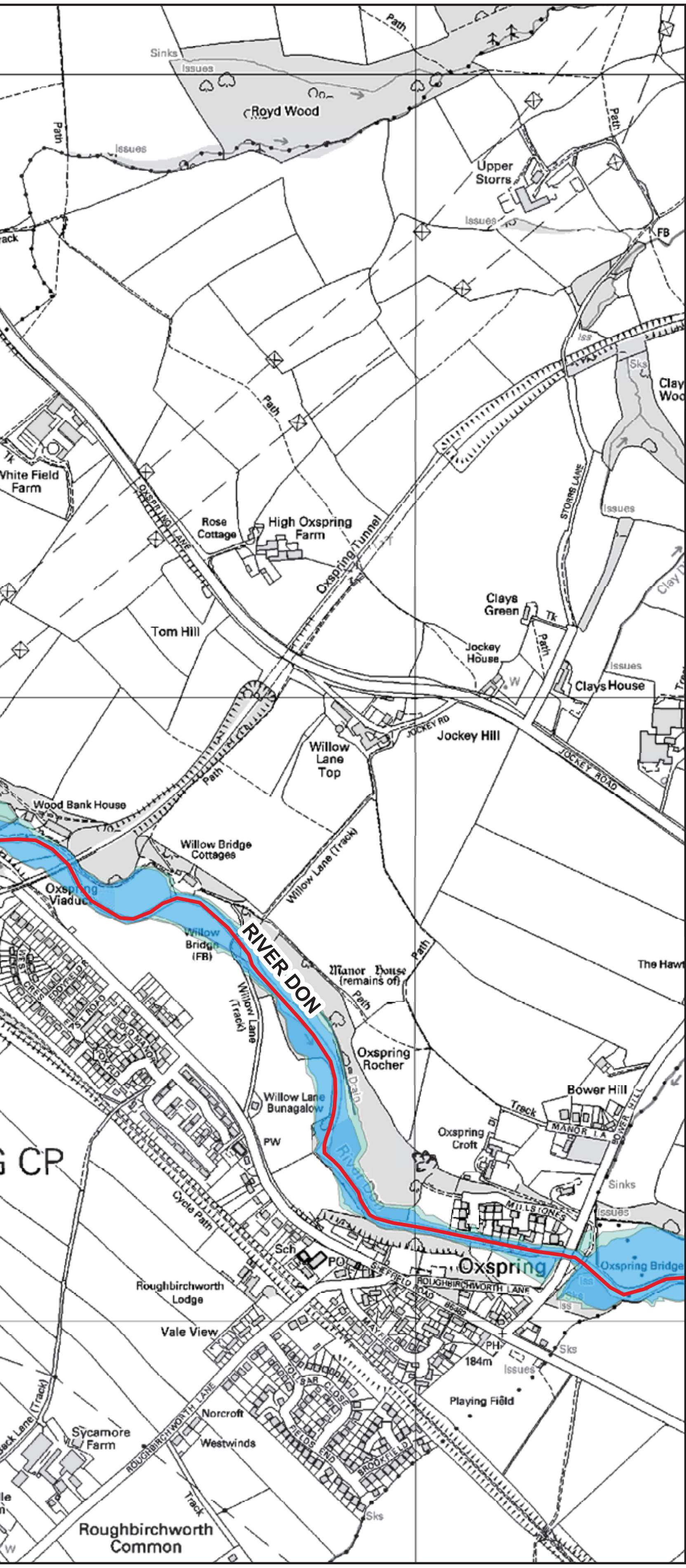
Cheryl Beech
Customers and Engagement Team

Direct Dial 0113 8196360
Email neyorkshire@environment-agency.gov.uk

Please note: I only work part time - my usual working days are Tuesday, Wednesday & Thursday no: 27158 River Don Model Results (Level - mAOD)

		Max water level (m AOD) - Undefended					
	Bed Level (m AOD)	1:25yr	1:50yr	1:75yr	1:100yr	1:200yr	1:1000yr
3u	185.50	188.02	188.21	188.22	188.23	188.33	188.75
1u	183.40	185.84	186.30	186.34	186.36	186.78	187.87
0u	182.81	185.17	185.49	185.51	185.52	185.77	186.63
7	181.43	183.54	183.74	183.75	183.76	183.91	184.39
2	180.49	182.60	182.80	182.81	182.83	183.00	183.53
3	178.98	181.98	182.22	182.24	182.26	182.45	183.05
4d	178.34	181.33	181.58	181.59	181.60	181.74	182.22
3u	177.97	180.86	181.13	181.14	181.14	181.17	181.59

ield- Date Created: 09/10/2013 Ref: 27158



Environment Agency

www.environment-agency.gov.uk

Scale: 1:10,000

N W E S

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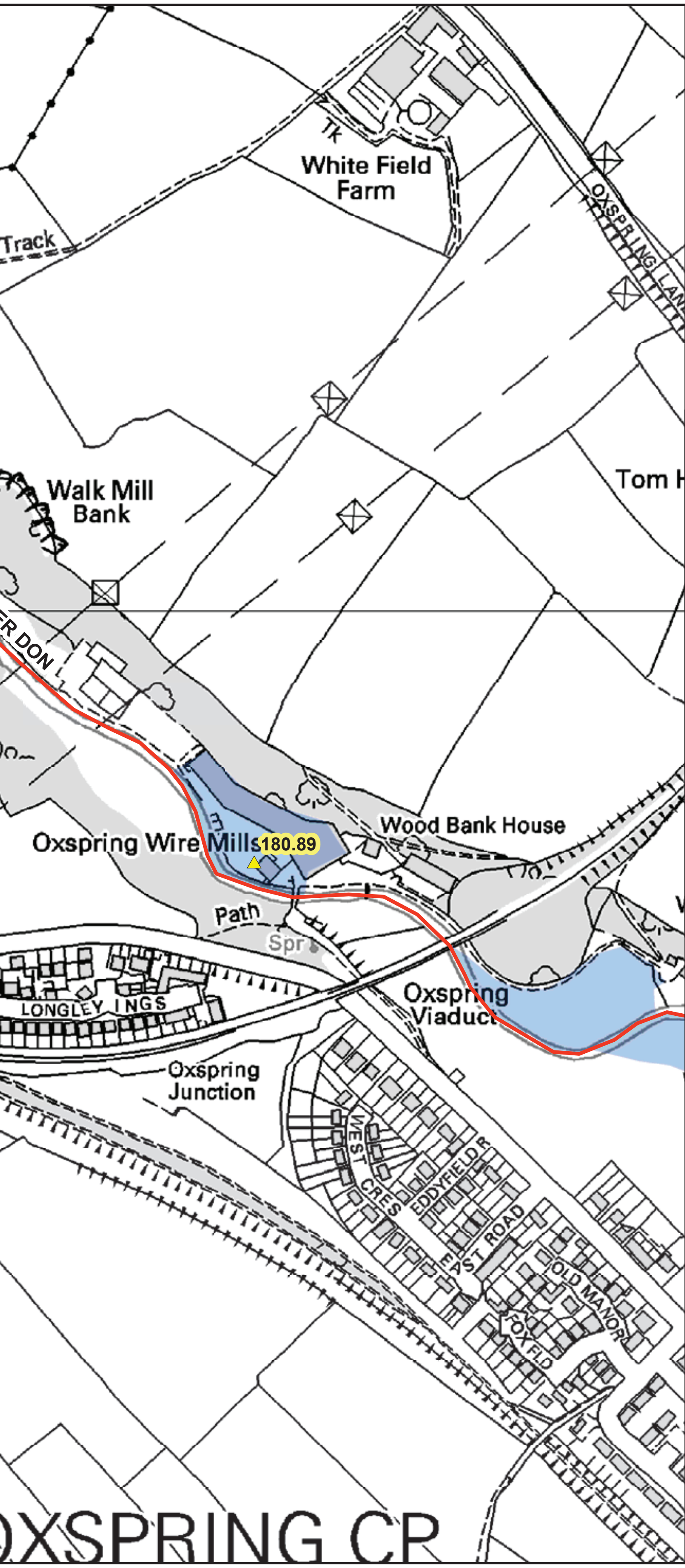
LEGEND

- Main River
- Flood Zone 3 (FZ3)
- Flood Zone 2 (FZ2)

uiries@environment-agency.gov.uk

one, Sheffield - dated: 09/10/2013 [Ref: 27158]



www.environment-agency.gov.uk

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Flood Extents

Legend

- Main River
- Autumn 2000 Flood Event Flood Level (m)
- 2007 Flood Events Flood Extent

ne, Sheffield- Date Created: 09/10/2013 Ref: 27158

Environment Agency

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N
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S

LEGEND

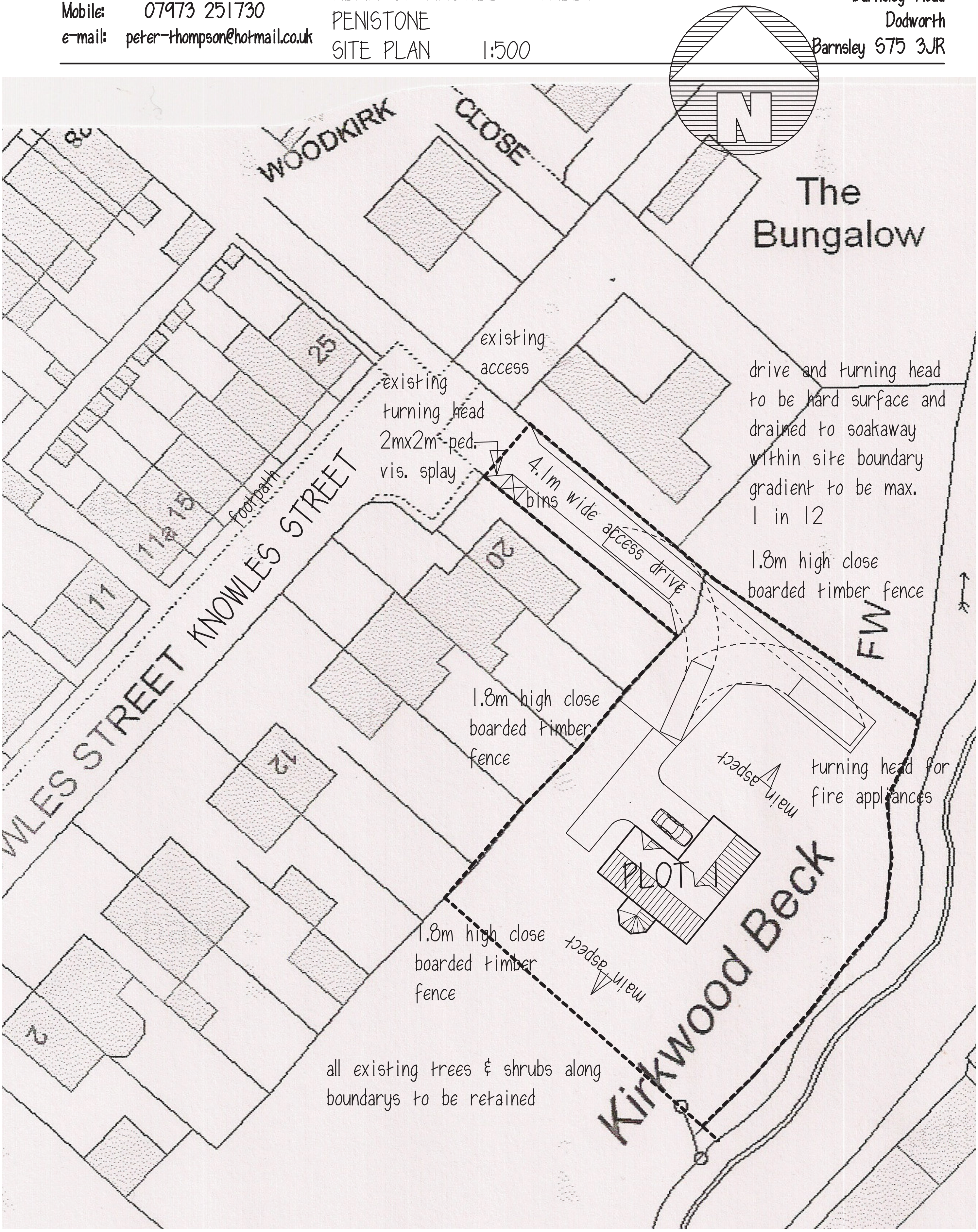
Main River

Node Points

APPENDIX 2 – Proposed Site Layout

Peter Thompson M.B.I.A.T.
Architectural Design Consultant Ltd.
Tel & Fax: 01226 201391
Mobile: 07973 251730
e-mail: peter-thompson@hotmail.co.uk
Linwood
Barnsley Road
Dodworth
Barnsley S75 3JR

PROPOSED DWELLING
REAR OF KNOWLES STREET
PENISTONE
SITE PLAN 1:500



APPENDIX 3 – Pre-Development Surface Water Runoff Rates

MasterDrain Hydrology 8.6	Company: KRS Environmental Ltd				Project: Rear of Knowles Street, Penistone, Sheffie	
	Item: Pre-development Surface Water Runoff Rates				Job Ref: KRS.0033.001	Sheet no.: 1
	Calc. by: KS	Date: 01/07/13	Checked by:	Date:	Approved by:	Date:

Hydrological Data:-

FSR Hydrology:-

Location = SHEFFIELD
Grid reference = SK3587
M5-60 (mm) = 18.9
r = 0.36
Soil runoff = 0.40
SAAR (mm/yr) = 775
WRAP = 3
Area = England & Wales
Hydrological area = 3
Hydrological zone = 8

Soil classification for WRAP type 3
i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Design data:-

Area = 0.001 Km² - 0.1 Ha - 1000 m² % Urbanisation = 0.00%

Calculation method:-

Runoff is calculated from:-

$$Q_{BAR(urban);} = Q_{BAR(rural)} (1 + URBAN)^{2NC}[1 + URBAN\{(21/CIND) -0.3\}]$$

where:-

NC varies with the value of SAAR:-
for 500<SAAR<1100 mm then NC = 0.92 - 0.00024SAAR
for 1100<SAAR<3000 mm then NC = 0.74 - 0.000082SAAR

CIND = 102.4SOIL + 0.28(CWI - 125) CWI = Catchment Wetness Index

CIND =29.275 CWI =83.269 NC =0.734

For areas less than 50Ha, a modified calculation which multiplies the 50Ha runoff value by the ratio of the site area to 50Ha is used
Reducing factor used for these calculations is 0.002

$Q_{BAR(rural)}$ = 0.383 (l/s)

$Q_{BAR(urban)}$ is then multiplied by a growth factor - GC(T) - for different storm return periods derived from EA publication W5-074/A.

Calculated data:-

Mean Annual Peak Flow $Q_{BAR(urban)}$ = 0.38 l/s

Values for $Q_{BAR(urban)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.000	0.000	0.000	0.001	0.001	0.001	cumecs
0.33	0.38	0.46	0.64	0.80	0.92	l/s
3.26	3.83	4.64	6.44	8.05	9.20	l/s/Ha
0.850	1.000	1.210	1.680	2.100	2.400	GC(T)

The above is based on the Institute of Hydrology Report 124 to which you are referred for further details (see Sect 7). Note that the 200 year growth curve was taken from W5-074/A.

For WRAP type 1 soils, CIND can become negative for lower values of SAAR. In this case the CIND value is multiplied by -1 to return a positive value (CIND is very small at this point).

APPENDIX 4 – Post-Development Surface Water Runoff Rates

Hydrological Data:-

FSR Hydrology:-

Location = SHEFFIELD
Grid reference = SK3587
M5-60 (mm) = 18.9
r = 0.36
Soil runoff = 0.40
SAAR (mm/yr) = 775
WRAP = 3
Area = England & Wales
Hydrological area = 3
Hydrological zone = 8

Soil classification for WRAP type 3

i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Design data:-

Area = 0.001 Km^2 - 0.1 Ha - 1000 m^2 % Urbanisation = 50.00%

Calculation method:-

Runoff is calculated from:-

$$Q_{BAR(urban);} = Q_{BAR(rural)} \ (1 + URBAN)^{2NC}[1 + URBAN\{(21/CIND) - 0.3\}]$$

where:-

NC varies with the value of SAAR:-
for 500<SAAR<1100 mm then NC = 0.92 - 0.00024SAAR
for 1100<SAAR<3000 mm then NC = 0.74 - 0.000082SAAR

CIND = 102.4SOIL + 0.28(CWI - 125) CWI = Catchment Wetness Index

CIND =29.275 CWI =83.269 NC =0.734

For areas less than 50Ha, a modified calculation which multiplies the 50Ha runoff value by the ratio of the site area to 50Ha is used
Reducing factor used for these calculations is 0.002

$Q_{BAR(rural)}$ = 0.383 (l/s)

$Q_{BAR(urban)}$ is then multiplied by a growth factor - GC(T) - for different storm return periods derived from EA publication W5-074/A.

Calculated data:-

Mean Annual Peak Flow $Q_{BAR(urban)}$ = 0.84 l/s

Values for $Q_{BAR(urban)}$

1 year	2 year	5 year	30 year	100 year	200 year	Units
0.001	0.001	0.001	0.001	0.002	0.002	cumecs
0.71	0.84	1.02	1.41	1.76	2.02	l/s
7.14	8.40	10.16	14.11	17.64	20.16	l/s/Ha
0.850	1.000	1.210	1.680	2.100	2.400	GC(T)

The above is based on the Institute of Hydrology Report 124 to which you are referred for further details (see Sect 7). Note that the 200 year growth curve was taken from W5-074/A.

For WRAP type 1 soils, CIND can become negative for lower values of SAAR. In this case the CIND value is multiplied by -1 to return a positive value (CIND is very small at this point).

APPENDIX 5 – Surface Water Runoff Storage Volumes

Company				Project	
KRS Environmental Ltd				Rear of Knowles Street, Penistone, Sheffie	
Item				Job Ref	Sheet no.
1 in 1 (+CC) Storage Volumes				KRS.0033.001	0
Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				

MasterDrain

Data:-

FSR Hydrology:-

Location	= SHEFFIELD	Grid reference	= SK3587
M5-60 (mm)	= 18.9	r	= 0.36
Soil index	= 0.40	SAAR (mm/yr)	= 775
Return period	= 1	WRAP	= 3
UCWI	= 81.3		

i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Runoff factor (RF) = 79.0, calculated from:-

Runoff factor = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7
where
PIMP = Impervious Area*100/(Impervious Area+Pervious Area)
UCWI = Calculated value for Wetness Index

Design data:-

Imperv. area	= 1500 m²	Pervious area	= 0 m²
Total area (TA)	= 1500 m²	Equiv area	= 1185 m² (TA x RF).
Discharge to drain	= 0.380 l/s	Areal reduction factor	= 1.000
Additional flow	= 0.00 l/s	Climate change factor	= 30

Calculated data:-

Time to max	= 500.0 mins	Storage volume	= 27.5 m³
Rainfall at max	= 3.94 mm/hr	Discharge rate per Ha	= 2.53 l/s/Ha

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len	Ovoid	Len	Box culvert	Len
100	3501.8	1125	27.7	400 x 600	152.8	500 x 500	110.0
150	1556.4	1200	24.3	600 x 900	66.5	500 x 750	73.3
225	691.7	1275	21.5	800 x 1200	37.4	500 x 1000	55.0
300	389.1	1350	19.2			750 x 1000	36.7
375	249.0	1425	17.2			750 x 1200	30.6
450	172.9	1500	15.6			750 x 1500	24.4
525	127.0	1575	14.1			1000 x 1000	27.5
600	97.3	1650	12.9			1000 x 1200	22.9
675	76.9	1725	11.8			1000 x 1500	18.3
750	62.3	1800	10.8			1000 x 1800	15.3
825	51.4	1875	10.0			1000 x 2000	13.7
900	43.2	1950	9.2			1500 x 1500	12.2
975	36.8	2025	8.5			1500 x 1800	10.2
1050	31.8	2100	7.9			1500 x 2000	9.2

Company				Project	
KRS Environmental Ltd				Rear of Knowles Street, Penistone, Sheffie	
Item				Job Ref	Sheet no.
1 in 1 (+CC) Storage Volumes				KRS.0033.001	1
Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				

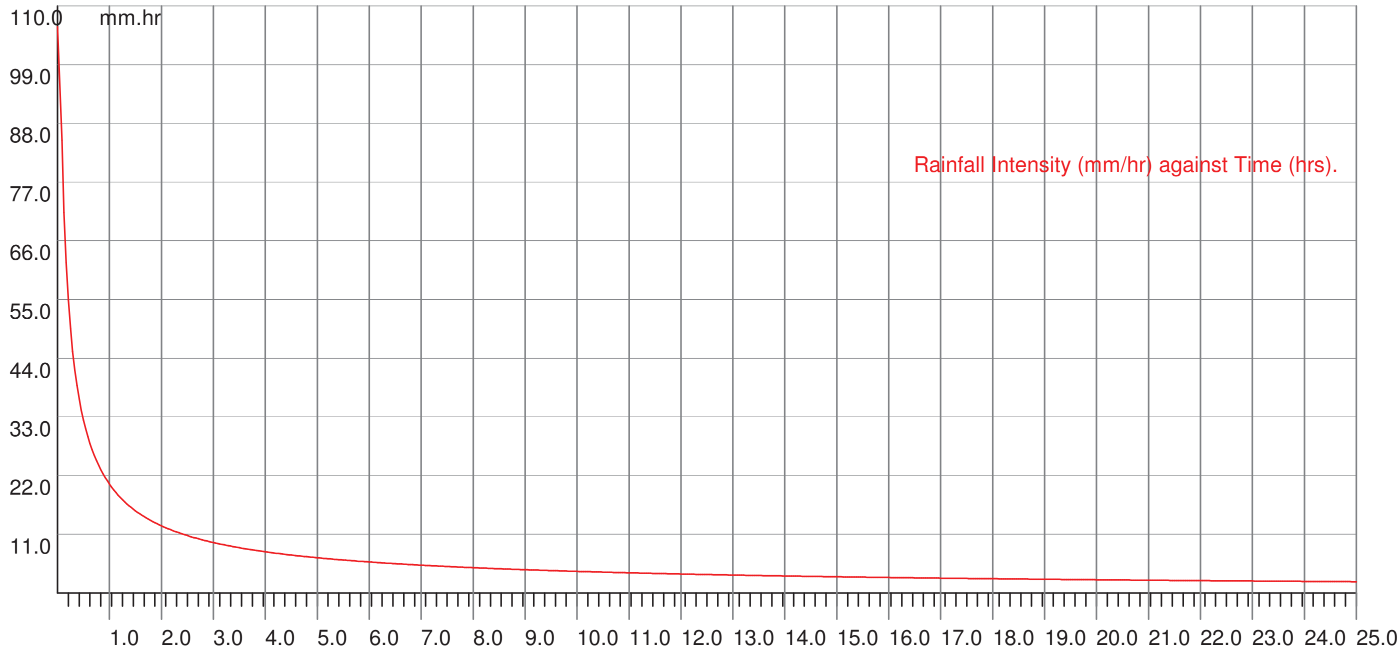
MasterDrain

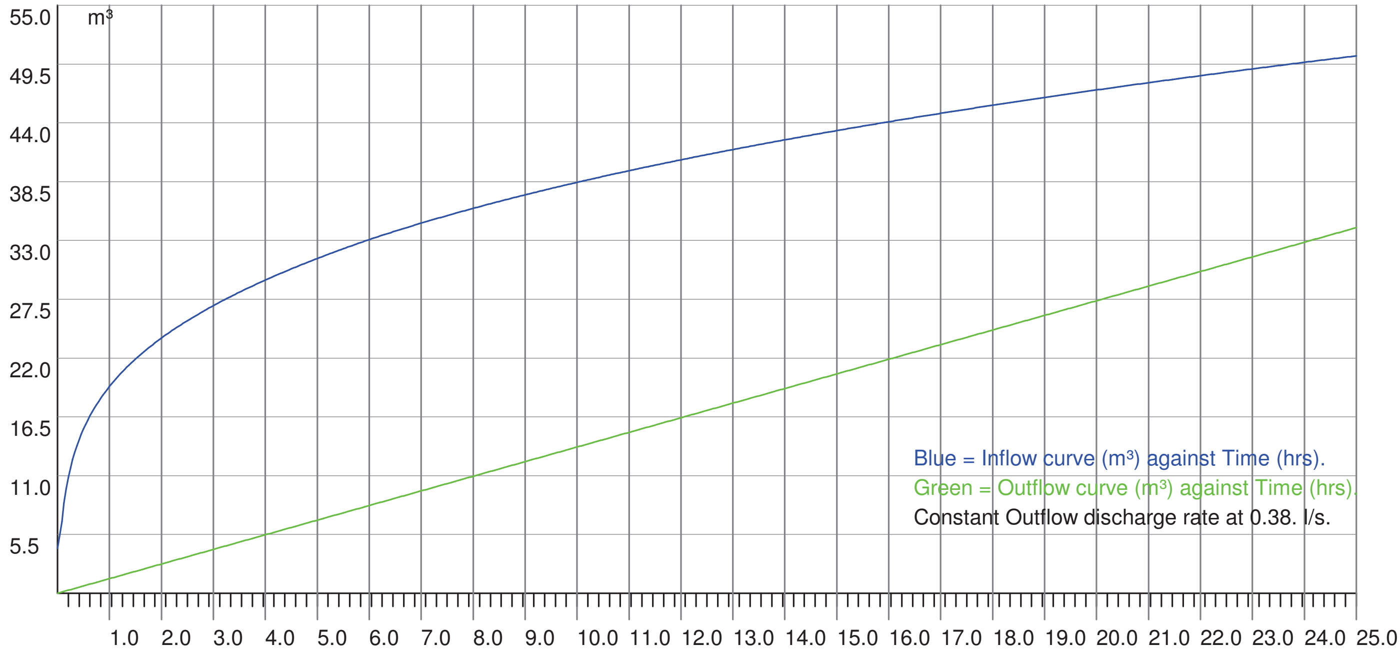
Data:-

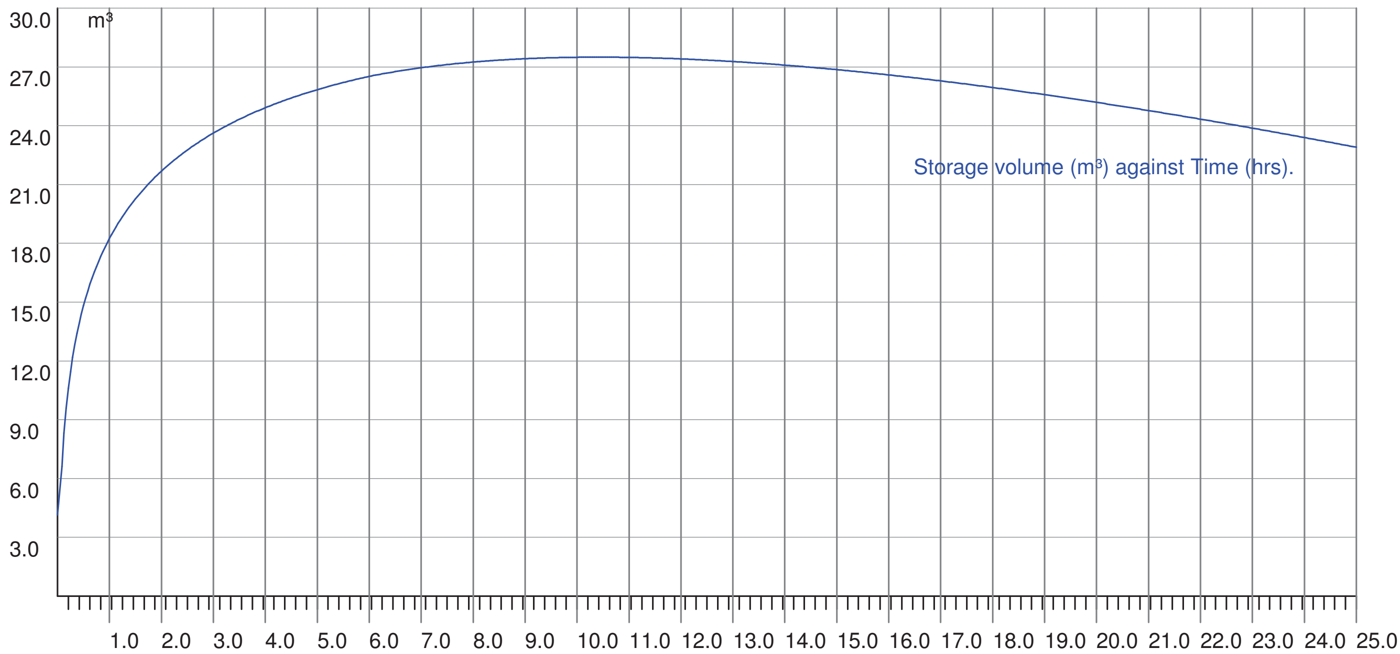
Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
20	36.0	14.376	0.456	13.920
40	23.0	18.251	0.912	17.339
60	17.0	20.725	1.368	19.357
80	14.0	22.608	1.824	20.784
100	12.0	24.160	2.280	21.880
120	11.0	25.497	2.736	22.761
140	10.0	26.683	3.192	23.491
160	9.0	27.755	3.648	24.107
180	8.0	28.738	4.104	24.634
200	8.0	29.651	4.560	25.091
220	7.0	30.505	5.016	25.489
240	7.0	31.310	5.472	25.838
260	6.0	32.074	5.928	26.146
280	6.0	32.801	6.384	26.417
300	6.0	33.483	6.840	26.643
320	5.0	34.125	7.296	26.829
340	5.0	34.739	7.752	26.987
360	5.0	35.327	8.208	27.119
380	5.0	35.892	8.664	27.228
400	5.0	36.436	9.120	27.316
420	4.0	36.961	9.576	27.385
440	4.0	37.469	10.032	27.437
460	4.0	37.960	10.488	27.472
480	4.0	38.436	10.944	27.492
500	4.0	38.898	11.400	27.498
520	4.0	39.347	11.856	27.491
540	4.0	39.784	12.312	27.472
560	4.0	40.210	12.768	27.442
580	4.0	40.625	13.224	27.401
600	3.0	41.030	13.680	27.350
620	3.0	41.425	14.136	27.289
640	3.0	41.812	14.592	27.220
660	3.0	42.190	15.048	27.142
680	3.0	42.560	15.504	27.056
700	3.0	42.922	15.960	26.962
720	3.0	43.277	16.416	26.861
740	3.0	43.626	16.872	26.754
760	3.0	43.967	17.328	26.639
780	3.0	44.303	17.784	26.519
800	3.0	44.632	18.240	26.392
820	3.0	44.956	18.696	26.260
840	3.0	45.274	19.152	26.122
860	3.0	45.587	19.608	25.979
880	3.0	45.895	20.064	25.831
900	3.0	46.198	20.520	25.678
920	3.0	46.496	20.976	25.520
940	3.0	46.790	21.432	25.358
960	2.0	47.079	21.888	25.191
980	2.0	47.364	22.344	25.020
1000	2.0	47.645	22.800	24.845
1020	2.0	47.922	23.256	24.666
1040	2.0	48.196	23.712	24.484
1060	2.0	48.466	24.168	24.298
1080	2.0	48.732	24.624	24.108
1100	2.0	48.995	25.080	23.915
1120	2.0	49.254	25.536	23.718
1140	2.0	49.510	25.992	23.518
1160	2.0	49.764	26.448	23.316
1180	2.0	50.014	26.904	23.110
1200	2.0	50.261	27.360	22.901

Storage volume (m^3) = 27.5 m^3

MasterDrain	Company			Project	
	KRS Environmental Ltd			Rear of Knowles Street, Penistone, Sheffie	
	Item			Job Ref	Sheet no.
	1 in 1 (+CC) Storage Volumes			KRS.0033.001	2
	Calc. by	Date: 01/07/13	Checked by	Date	Approved by	Date







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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.

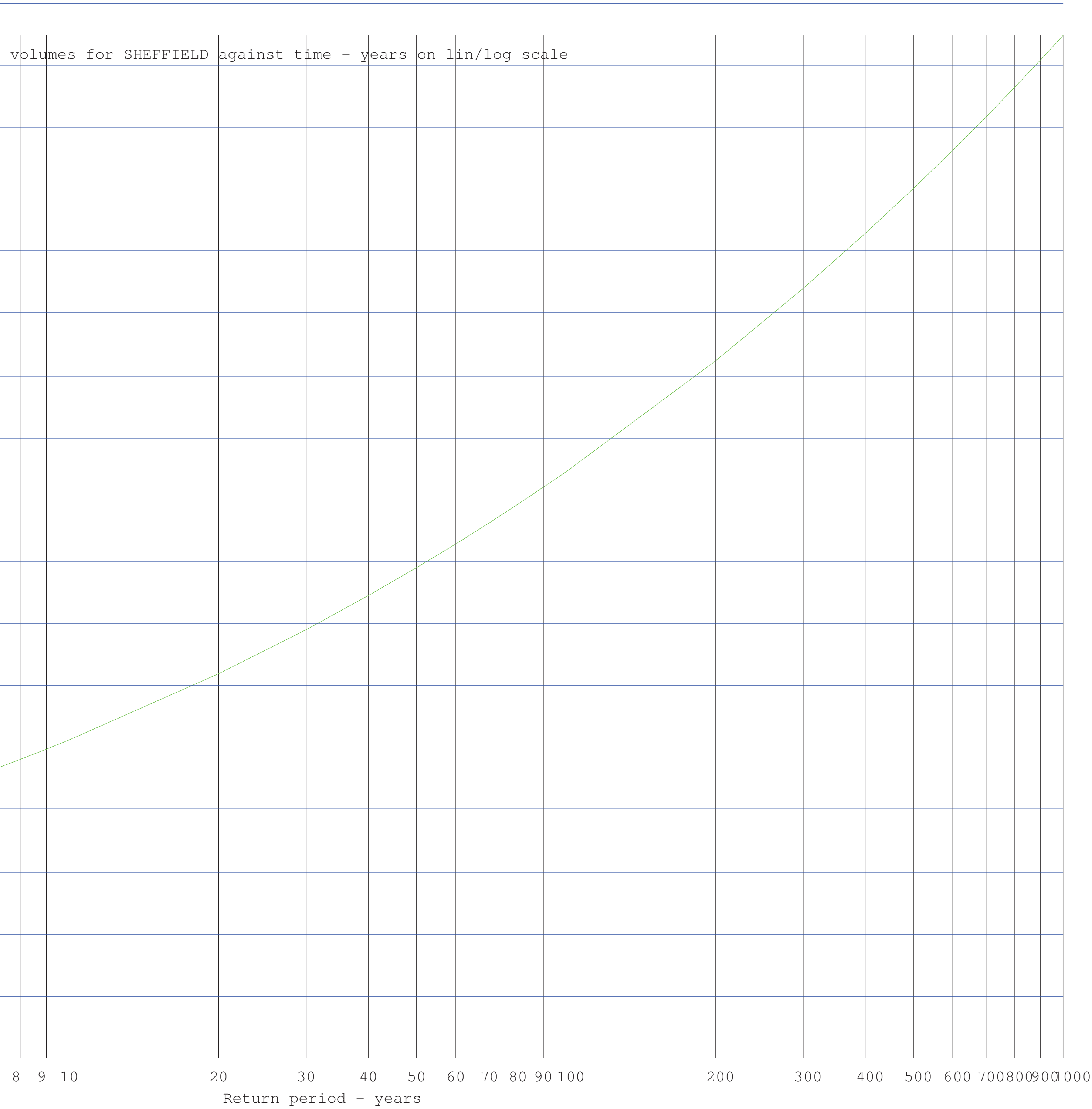
Why do the two methods give different results?

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.

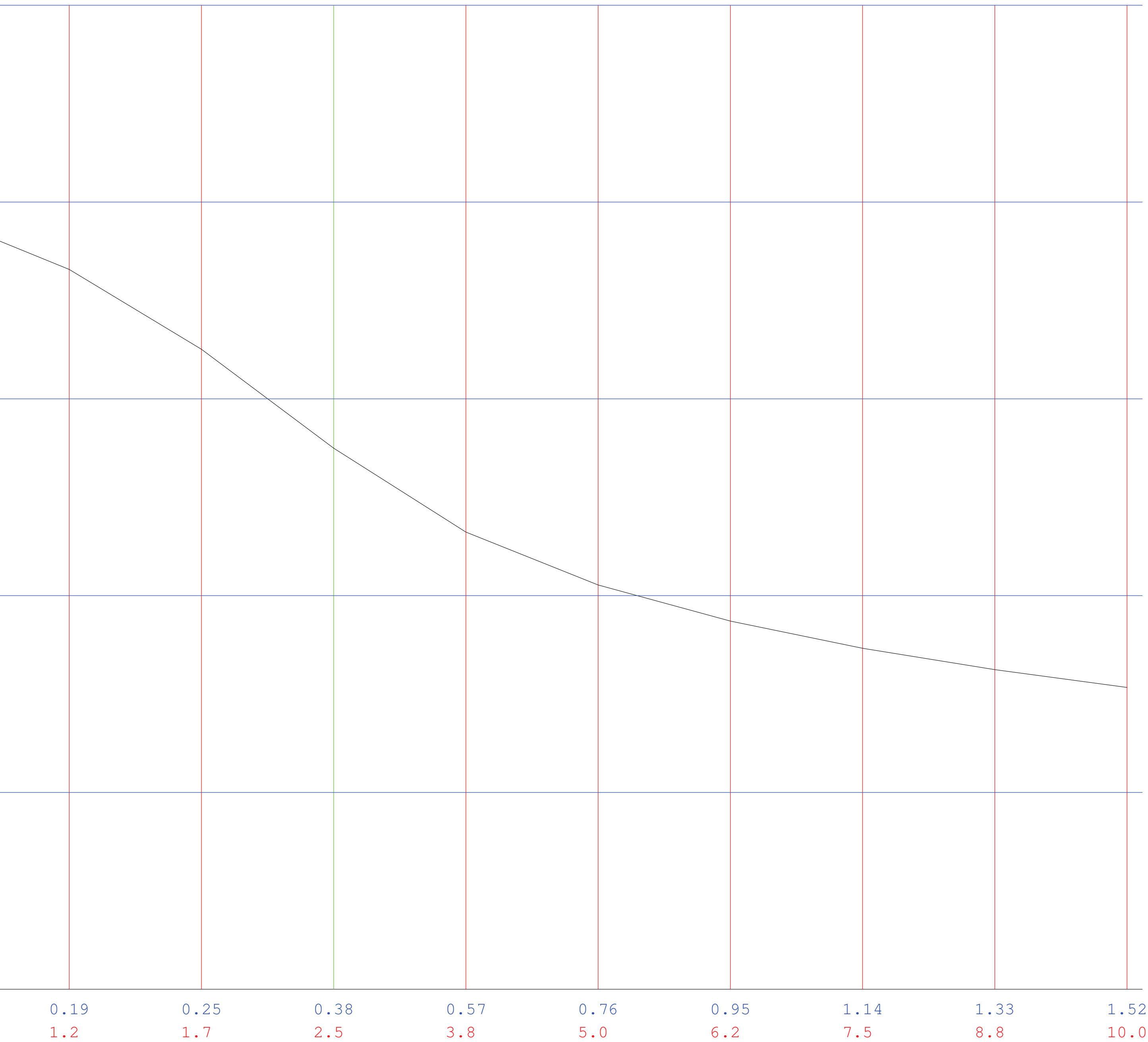
The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated 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.


volumes for SHEFFIELD against time - years on lin/log scale
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Return period - years

s for SHEFFIELD against varying discharge rates

ge rate= 0.4



Company				Project	
KRS Environmental Ltd				Rear of Knowles Street, Penistone, Sheffie	
Item				Job Ref	Sheet no.
1 in 100 (+CC) Storage Volumes				KRS.0033.001	0
Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				

MasterDrain

Data:-

FSR Hydrology:-

Location	= SHEFFIELD	Grid reference	= SK3587
M5-60 (mm)	= 18.9	r	= 0.36
Soil index	= 0.40	SAAR (mm/yr)	= 775
Return period	= 100	WRAP	= 3
UCWI	= 81.3		

i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Runoff factor (RF) = 79.0, calculated from:-

Runoff factor = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7
where
PIMP = Impervious Area*100/(Impervious Area+Pervious Area)
UCWI = Calculated value for Wetness Index

Design data:-

Imperv. area	= 1500 m²	Pervious area	= 0 m²
Total area (TA)	= 1500 m²	Equiv area	= 1185 m² (TA x RF).
Discharge to drain	= 0.380 l/s	Areal reduction factor	= 1.000
Additional flow	= 0.00 l/s	Climate change factor	= 30

Calculated data:-

Time to max	= 1215.0 mins	Storage volume	= 98.4 m³
Rainfall at max	= 5.26 mm/hr	Discharge rate per Ha	= 2.53 l/s/Ha

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len
100	12533.9	1125	99.0
150	5570.6	1200	87.0
225	2475.8	1275	77.1
300	1392.7	1350	68.8
375	891.3	1425	61.7
450	619.0	1500	55.7
525	454.7	1575	50.5
600	348.2	1650	46.0
675	275.1	1725	42.1
750	222.8	1800	38.7
825	184.2	1875	35.7
900	154.7	1950	33.0
975	131.8	2025	30.6
1050	113.7	2100	28.4

Ovoid	Len
400 x 600	546.8
600 x 900	238.1
800 x 1200	133.9

Box culvert	Len
500 x 500	393.7
500 x 750	262.5
500 x 1000	196.8
750 x 1000	131.2
750 x 1200	109.4
750 x 1500	87.5
1000 x 1000	98.4
1000 x 1200	82.0
1000 x 1500	65.6
1000 x 1800	54.7
1000 x 2000	49.2
1500 x 1500	43.7
1500 x 1800	36.5
1500 x 2000	32.8

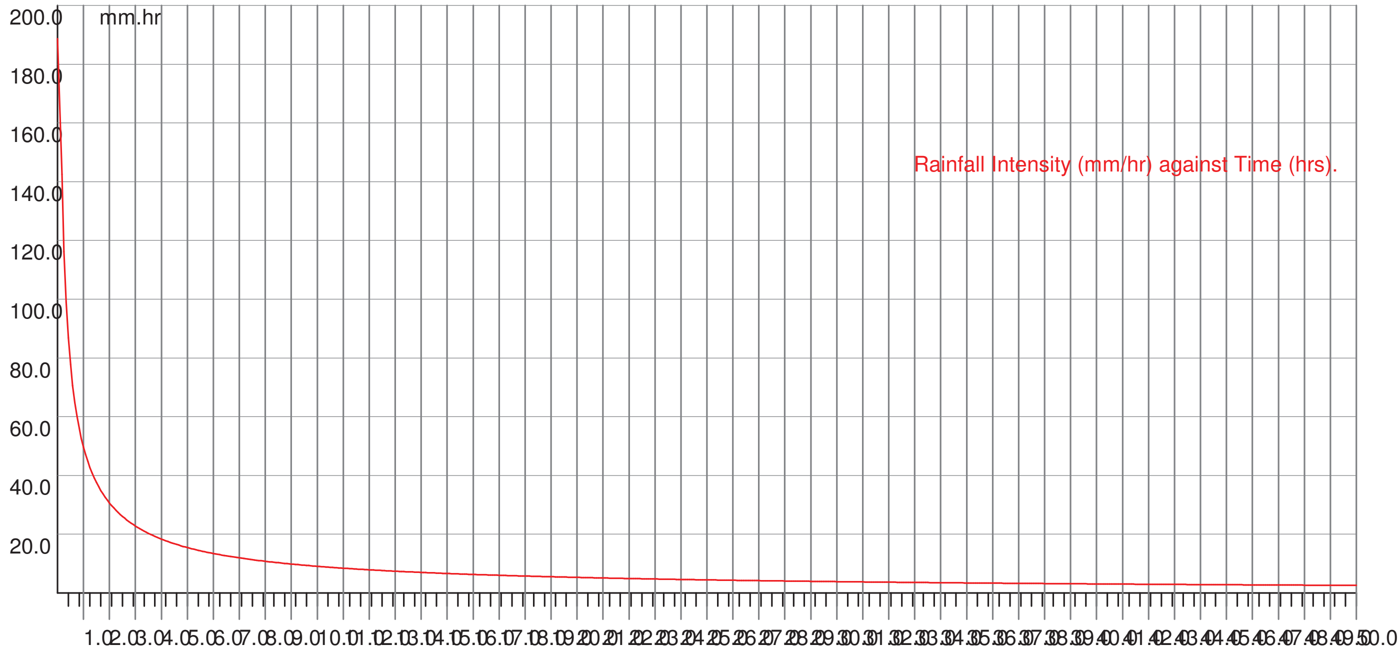
MasterDrain	Company: KRS Environmental Ltd		Project: Rear of Knowles Street, Penistone, Sheffie
	Item: 1 in 100 (+CC) Storage Volumes		Job Ref: KRS.0033.001 / Sheet no.: 1
	Calc. by: / Date: 01/07/13	Checked by: / Date:	Approved by: / Date:

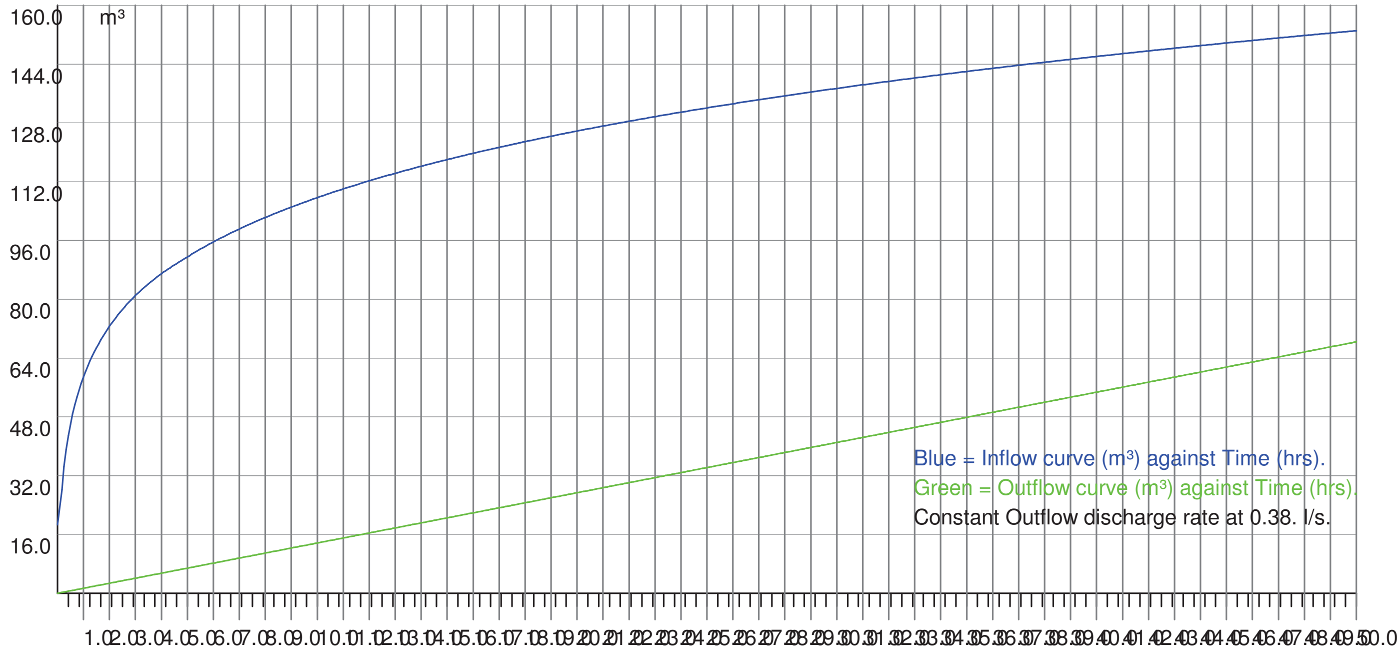
Data:-

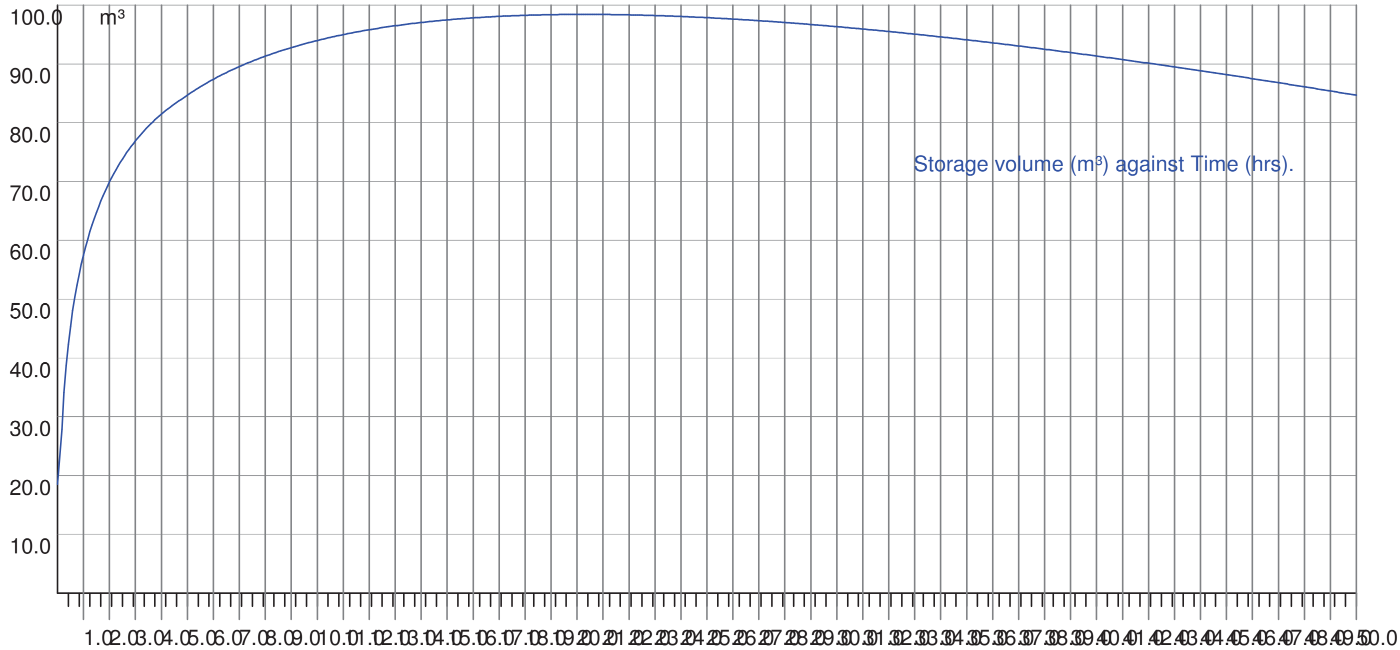
Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
50	56.0	55.382	1.140	54.242
100	35.0	68.937	2.280	66.657
150	26.0	77.240	3.420	73.820
200	21.0	83.193	4.560	78.633
250	18.0	87.777	5.700	82.077
300	15.0	91.532	6.840	84.692
350	14.0	94.957	7.980	86.977
400	12.0	97.997	9.120	88.877
450	11.0	100.735	10.260	90.475
500	10.0	103.232	11.400	91.832
550	10.0	105.529	12.540	92.989
600	9.0	107.659	13.680	93.979
650	9.0	109.646	14.820	94.826
700	8.0	111.510	15.960	95.550
750	8.0	113.266	17.100	96.166
800	7.0	114.927	18.240	96.687
850	7.0	116.504	19.380	97.124
900	7.0	118.005	20.520	97.485
950	6.0	119.438	21.660	97.778
1000	6.0	120.810	22.800	98.010
1050	6.0	122.125	23.940	98.185
1100	6.0	123.390	25.080	98.310
1150	5.0	124.607	26.220	98.387
1200	5.0	125.780	27.360	98.420
1250	5.0	126.913	28.500	98.413
1300	5.0	128.009	29.640	98.369
1350	5.0	129.070	30.780	98.290
1400	5.0	130.099	31.920	98.179
1450	5.0	131.097	33.060	98.037
1500	4.0	132.067	34.200	97.867
1550	4.0	133.010	35.340	97.670
1600	4.0	133.928	36.480	97.448
1650	4.0	134.822	37.620	97.202
1700	4.0	135.694	38.760	96.934
1750	4.0	136.544	39.900	96.644
1800	4.0	137.374	41.040	96.334
1850	4.0	138.185	42.180	96.005
1900	4.0	138.977	43.320	95.657
1950	4.0	139.752	44.460	95.292
2000	4.0	140.511	45.600	94.911
2050	3.0	141.253	46.740	94.513
2100	3.0	141.981	47.880	94.101
2150	3.0	142.694	49.020	93.674
2200	3.0	143.393	50.160	93.233
2250	3.0	144.079	51.300	92.779
2300	3.0	144.752	52.440	92.312
2350	3.0	145.413	53.580	91.833
2400	3.0	146.062	54.720	91.342
2450	3.0	146.700	55.860	90.840
2500	3.0	147.327	57.000	90.327
2550	3.0	147.943	58.140	89.803
2600	3.0	148.549	59.280	89.269
2650	3.0	149.145	60.420	88.725
2700	3.0	149.732	61.560	88.172
2750	3.0	150.310	62.700	87.610
2800	3.0	150.879	63.840	87.039
2850	3.0	151.439	64.980	86.459
2900	3.0	151.991	66.120	85.871
2950	3.0	152.535	67.260	85.275
3000	3.0	153.071	68.400	84.671

Storage volume (m^3) = 98.4 m^3

MasterDrain	Company KRS Environmental Ltd			Project Rear of Knowles Street, Penistone, Sheffie	
	Item 1 in 100 (+CC) Storage Volumes			Job Ref KRS.0033.001	Sheet no. 2
	Calc. by	Date 01/07/13	Checked by	Date	Approved by	Date







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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
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6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.

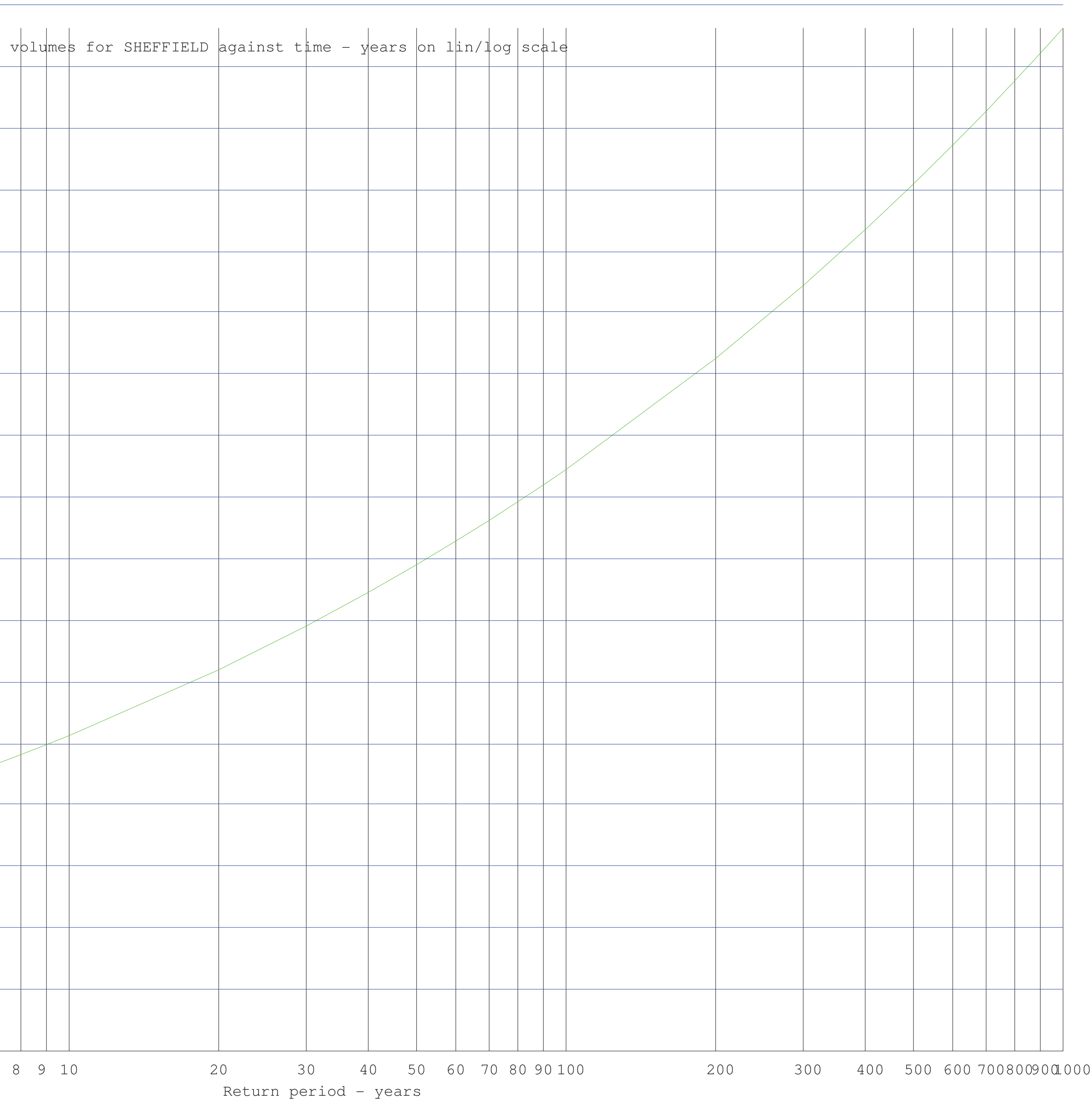
Why do the two methods give different results?

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.

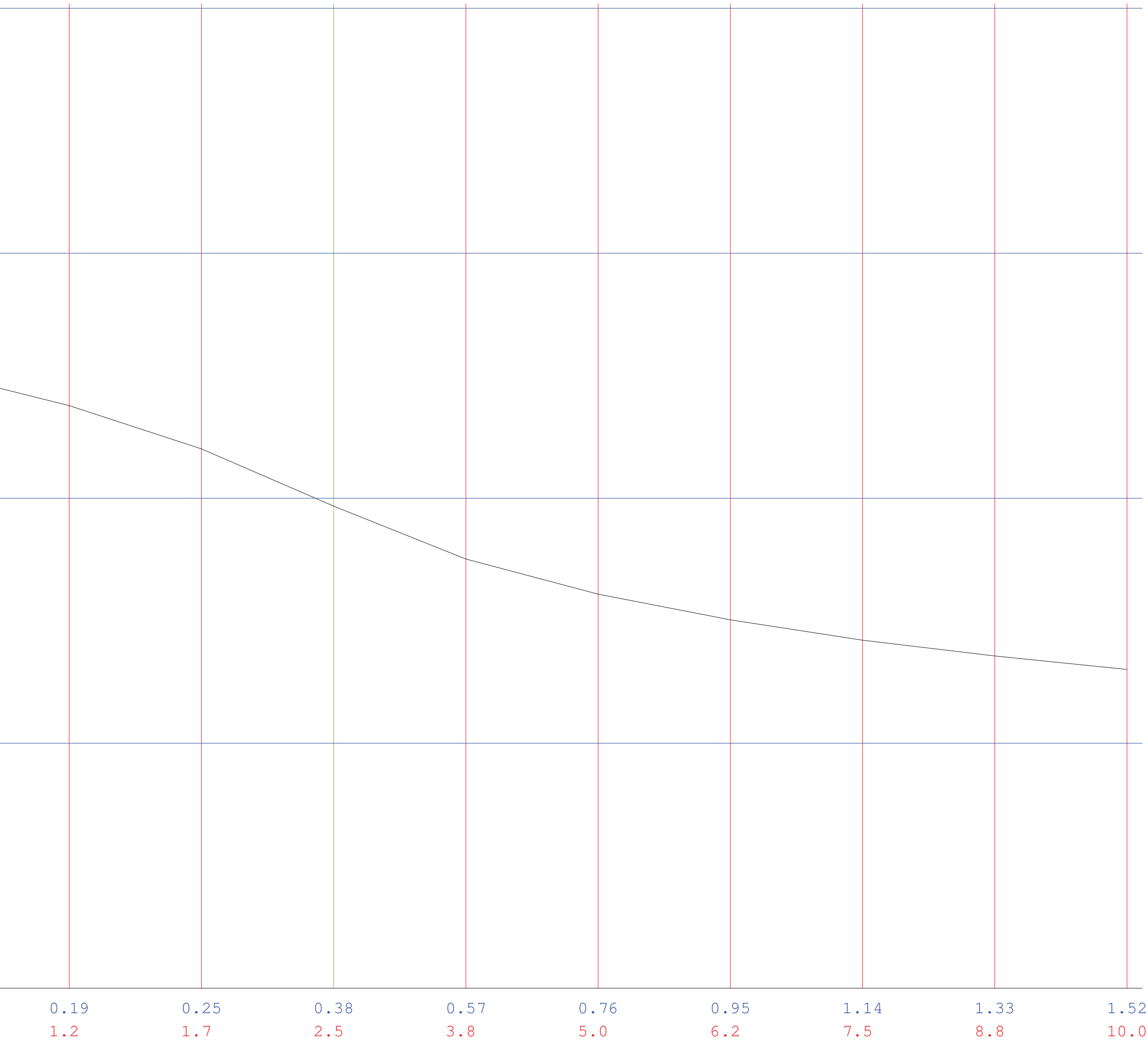
The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated 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.


volumes for SHEFFIELD against time - years on lin/log scale
8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000
Return period - years

s for SHEFFIELD against varying discharge rates

ge rate= 0.4



Company	Project	
KRS Environmental Ltd	Rear of Knowles Street, Penistone, Sheffie	

MasterDrain

Item	Job Ref	Sheet no.
1 in 30 (+CC) Storage Volumes	KRS.0033.001	0

Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				

Data:-

FSR Hydrology:-

Location = SHEFFIELD
M5-60 (mm) = 18.9
Soil index = 0.40
Return period = 30
UCWI = 81.3

Grid reference = SK3587
r = 0.36
SAAR (mm/yr) = 775
WRAP = 3

i) Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in eastern England;
ii) Permeable soils with shallow ground water in low-lying areas;
iii) Mixed areas of permeable and impermeable soils, in approximately equal proportions.

Runoff factor (RF) = 79.0, calculated from:-

Runoff factor = (0.829*PIMP)+(25*SOIL)+(0.078*UCWI)-20.7
where
PIMP = Impervious Area*100/(Impervious Area+Pervious Area)
UCWI = Calculated value for Wetness Index

Design data:-

Imperv. area = 1500 m²
Total area (TA) = 1500 m²
Discharge to drain = 0.380 l/s
Additional flow = 0.00 l/s

Pervious area = 0 m²
Equiv area = 1185 m² (TA x RF).
Areal reduction factor = 1.000
Climate change factor = 30

Calculated data:-

Time to max = 1000.0 mins
Rainfall at max = 4.80 mm/hr

Storage volume = 71.9 m³
Discharge rate per Ha = 2.53 l/s/Ha

Rainfall intensities calculated using the Wallingford Procedure

Storage lengths for initial calculation (x 1.1, 1.2, 1.3 or 1.5 as above if required) :-

Diam	Len	Diam	Len
100	9159.4	1125	72.4
150	4070.8	1200	63.6
225	1809.3	1275	56.3
300	1017.7	1350	50.3
375	651.3	1425	45.1
450	452.3	1500	40.7
525	332.3	1575	36.9
600	254.4	1650	33.6
675	201.0	1725	30.8
750	162.8	1800	28.3
825	134.6	1875	26.1
900	113.1	1950	24.1
975	96.4	2025	22.3
1050	83.1	2100	20.8

Ovoid	Len
400 x 600	399.6
600 x 900	174.0
800 x 1200	97.9

Box culvert	Len
500 x 500	287.7
500 x 750	191.8
500 x 1000	143.8
750 x 1000	95.9
750 x 1200	79.9
750 x 1500	63.9
1000 x 1000	71.9
1000 x 1200	59.9
1000 x 1500	47.9
1000 x 1800	40.0
1000 x 2000	36.0
1500 x 1500	32.0
1500 x 1800	26.6
1500 x 2000	24.0

Company				Project	
KRS Environmental Ltd				Rear of Knowles Street, Penistone, Sheffie	
Item				Job Ref	Sheet no.
1 in 30 (+CC) Storage Volumes				KRS.0033.001	1
Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				

MasterDrain

Data:-

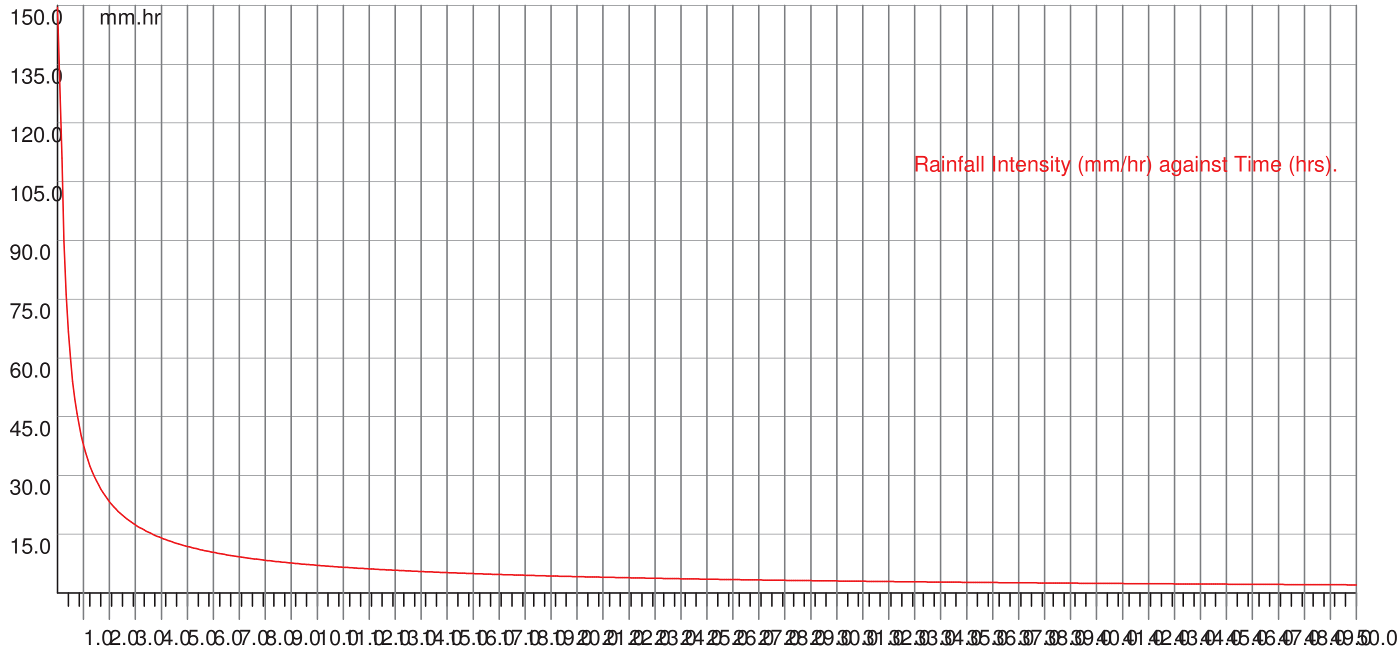
Time (mins)	Rain mm/hr	Inflow (m3)	Outflow (m3)	Balance (m3)
50	43.0	42.205	1.140	41.065
100	27.0	52.409	2.280	50.129
150	20.0	58.812	3.420	55.392
200	16.0	63.526	4.560	58.966
250	14.0	67.256	5.700	61.556
300	12.0	70.370	6.840	63.530
350	11.0	73.168	7.980	65.188
400	10.0	75.662	9.120	66.542
450	9.0	77.918	10.260	67.658
500	8.0	79.982	11.400	68.582
550	8.0	81.888	12.540	69.348
600	7.0	83.660	13.680	69.980
650	7.0	85.319	14.820	70.499
700	6.0	86.878	15.960	70.918
750	6.0	88.352	17.100	71.252
800	6.0	89.749	18.240	71.509
850	5.0	91.078	19.380	71.698
900	5.0	92.347	20.520	71.827
950	5.0	93.560	21.660	71.900
1000	5.0	94.724	22.800	71.924
1050	5.0	95.842	23.940	71.902
1100	4.0	96.919	25.080	71.839
1150	4.0	97.957	26.220	71.737
1200	4.0	98.960	27.360	71.600
1250	4.0	99.930	28.500	71.430
1300	4.0	100.870	29.640	71.230
1350	4.0	101.781	30.780	71.001
1400	4.0	102.666	31.920	70.746
1450	4.0	103.526	33.060	70.466
1500	4.0	104.362	34.200	70.162
1550	3.0	105.177	35.340	69.837
1600	3.0	105.971	36.480	69.491
1650	3.0	106.745	37.620	69.125
1700	3.0	107.501	38.760	68.741
1750	3.0	108.239	39.900	68.339
1800	3.0	108.961	41.040	67.921
1850	3.0	109.667	42.180	67.487
1900	3.0	110.357	43.320	67.037
1950	3.0	111.034	44.460	66.574
2000	3.0	111.696	45.600	66.096
2050	3.0	112.346	46.740	65.606
2100	3.0	112.983	47.880	65.103
2150	3.0	113.608	49.020	64.588
2200	3.0	114.221	50.160	64.061
2250	3.0	114.823	51.300	63.523
2300	3.0	115.415	52.440	62.975
2350	2.0	115.997	53.580	62.417
2400	2.0	116.568	54.720	61.848
2450	2.0	117.131	55.860	61.271
2500	2.0	117.684	57.000	60.684
2550	2.0	118.228	58.140	60.088
2600	2.0	118.764	59.280	59.484
2650	2.0	119.292	60.420	58.872
2700	2.0	119.811	61.560	58.251
2750	2.0	120.323	62.700	57.623
2800	2.0	120.828	63.840	56.988
2850	2.0	121.326	64.980	56.346
2900	2.0	121.816	66.120	55.696
2950	2.0	122.300	67.260	55.040
3000	2.0	122.777	68.400	54.377

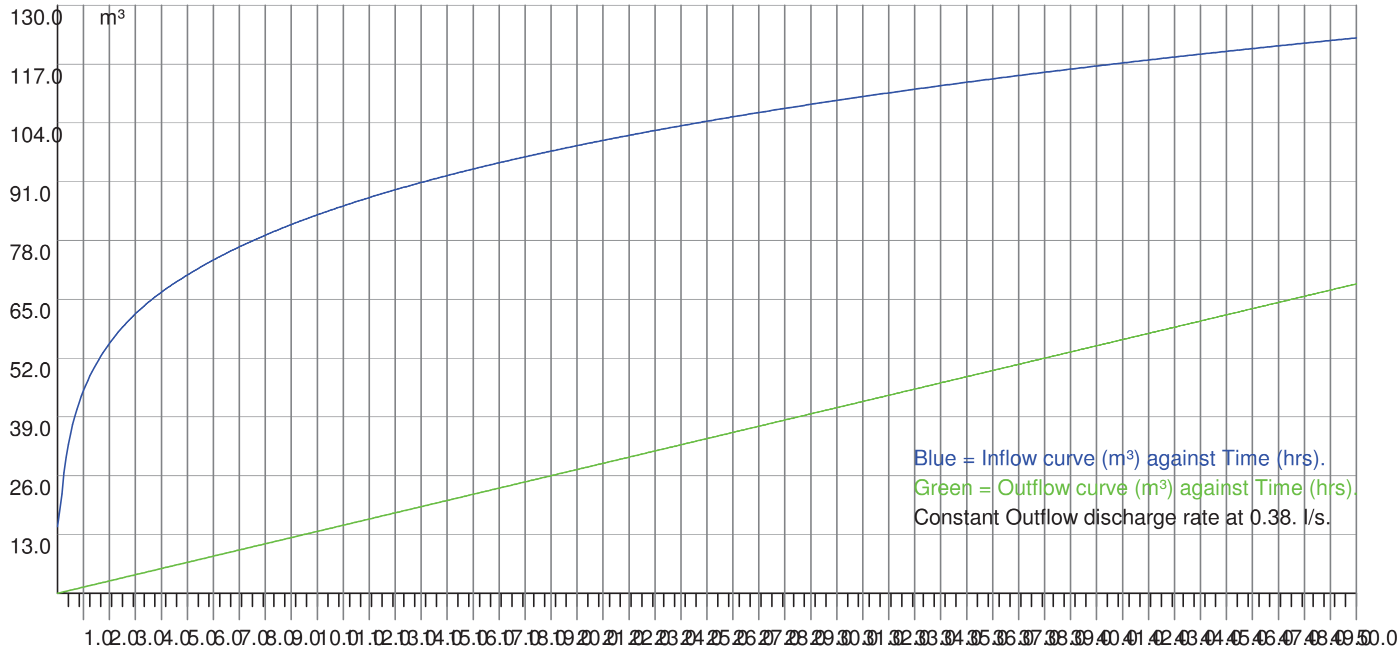
Storage volume (m^3) = 71.9 m^3

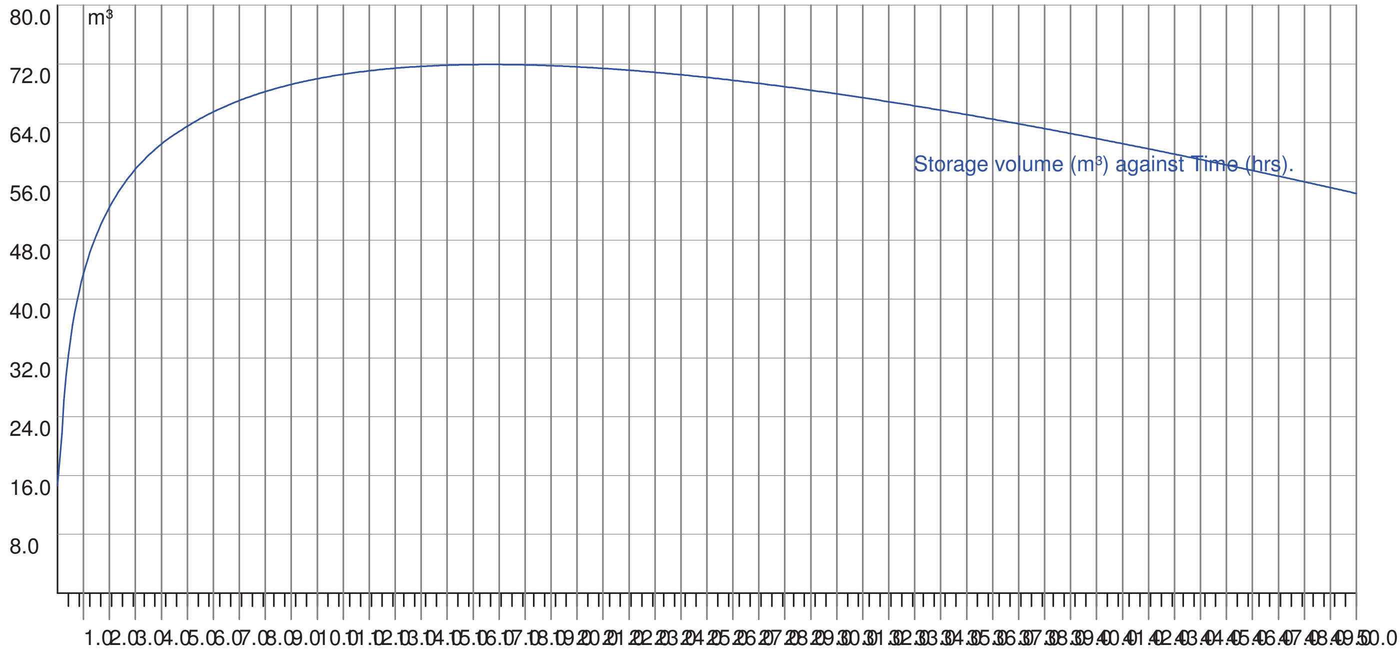
MasterDrain

Company	Project	
KRS Environmental Ltd	**Rear of Knowles Street, Penistone, Sheffie**	
Item	**Job Ref**	**Sheet no.**
1 in 30 (+CC) Storage Volumes	**KRS.0033.001**	**2**

Calc. by	Date	Checked by	Date	Approved by	Date
	01/07/13				







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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
3) The balance is calculated from the inflow minus the outflow.
4) The storage volume is the maximum value of the balance curve.
5) This method was described by Davis (1963) - see Butler & Davies, 2nd edition, p294
6) References to 'storm duration' relate only to the hydrograph method (qv).
7) 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 outflow is regarded as constant for the duration of the storm; i.e. no allowance is made for the changing head behind the flow restrictor.*
5) The balance is calculated from the inflow minus the outflow.
6) The storage volume is the sum of the balance values for each step.
7) 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.

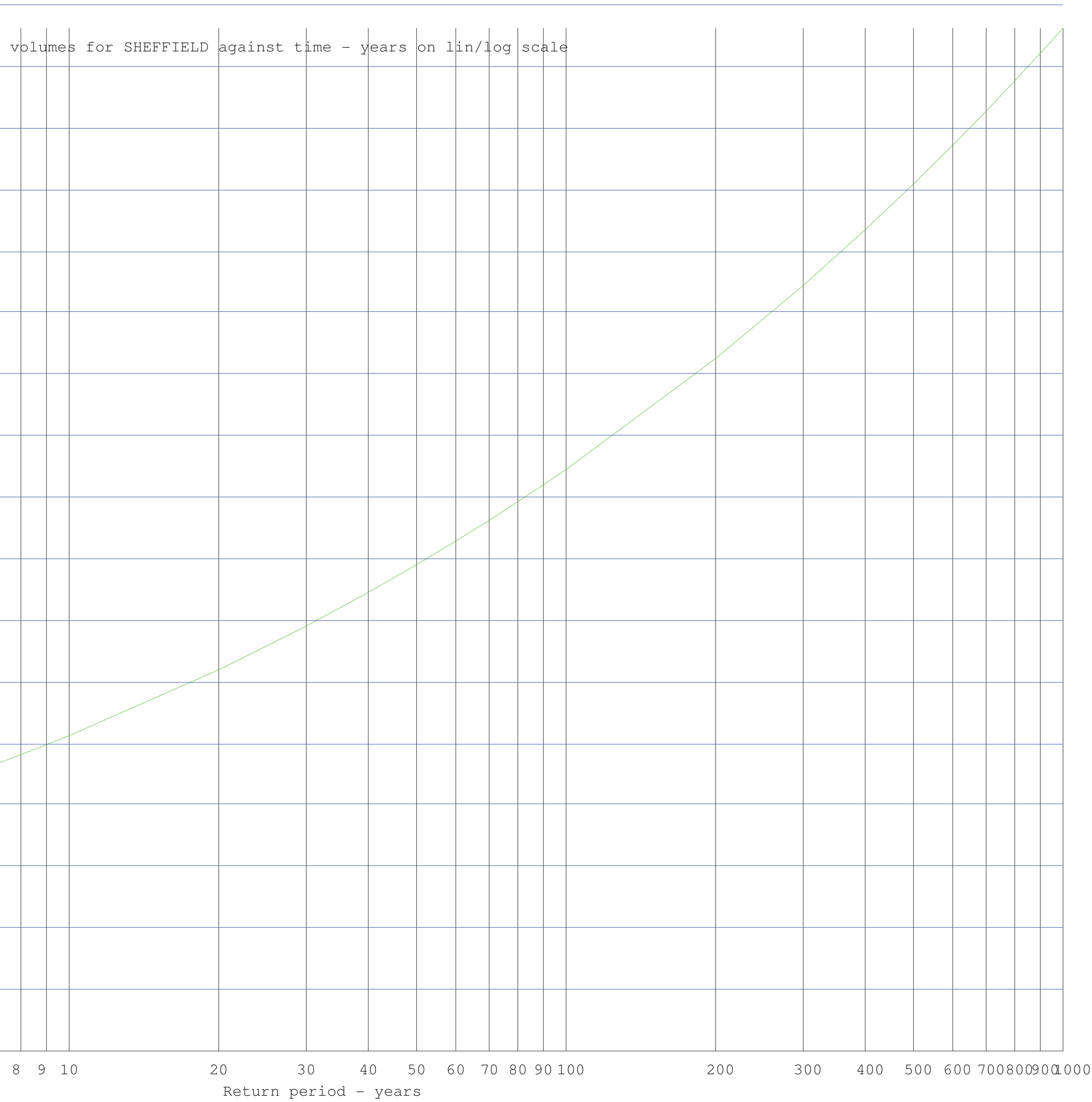
Why do the two methods give different results?

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.

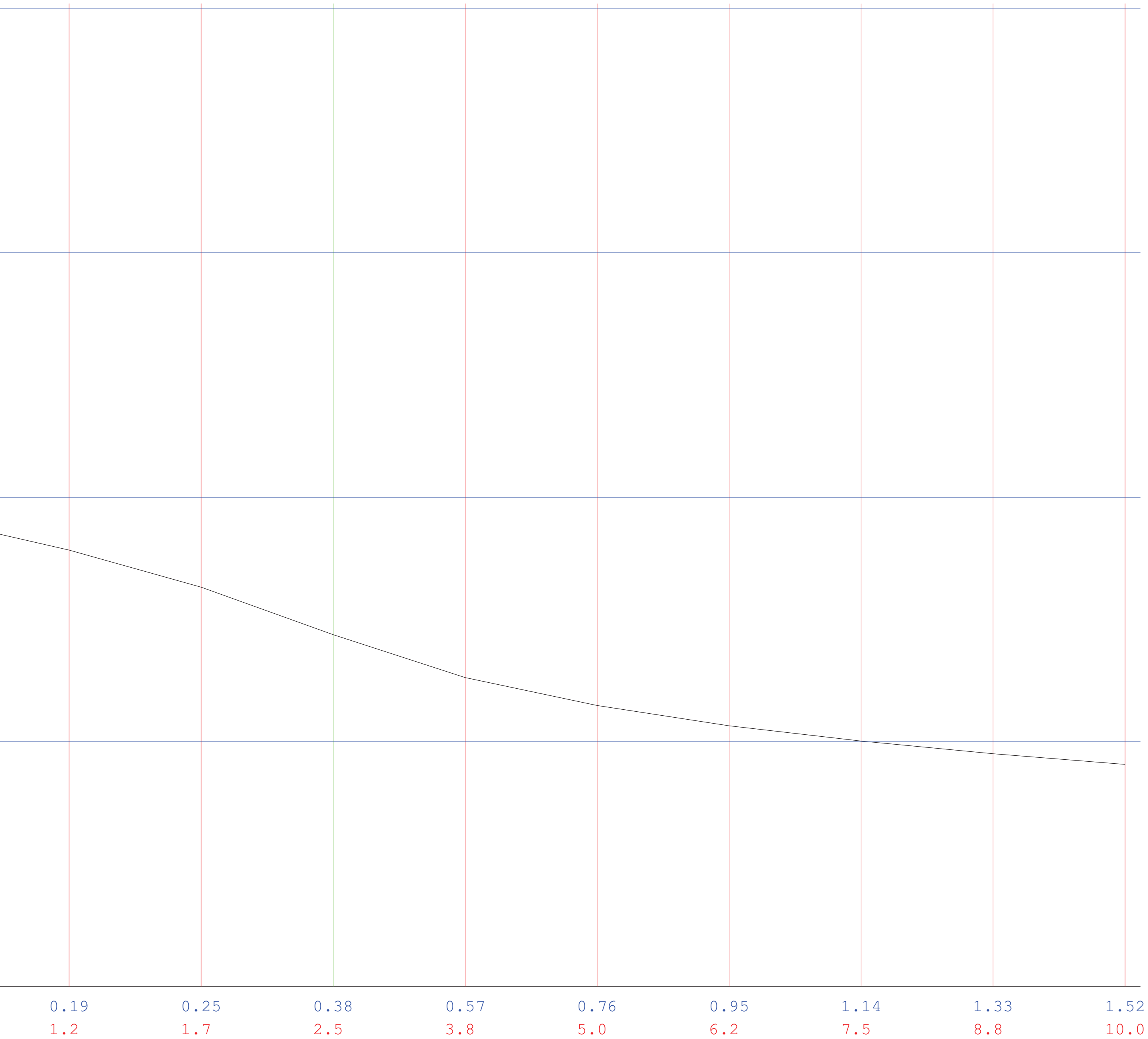
The hydrograph method uses a standard curve for either Winter or Summer storms. Traditionally these are symmetrical about the central peak. UK rainfall does not fit into this convenient curve, so the calculations are dealing with a stylised set of data. The mean intensity for the storm is calculated 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.


volumes for SHEFFIELD against time - years on lin/log scale
8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000
Return period - years

s for SHEFFIELD against varying discharge rates

ge rate= 0.4



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