# North West Leicestershire District Council

# Strategic Flood Risk Assessment

**Final Report**

**May 2008**

Planning Policy and Regeneration
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# Glossary of Terms

| Term | Meaning / Definition |
|---|---|
| AEP | Annual Exceedance Probability |
| AONB | Area of Outstanding Natural Beauty |
| CFMP | Catchment Flood Management Plan |
| Defra | Department of Food and Rural Affairs |
| DTM | Digital Terrain Model |
| EA | Environment Agency |
| EiP | Examination in Public |
| FRA | Flood Risk Assessment |
| GIS | Geographical Information System |
| LiDAR | Light Detection and Ranging |
| LDD | Local Development Document |
| LDF | Local Development Framework |
| LNR | Local Nature Reserve |
| LP | Local Plan |
| LPA | Local Planning Authority |
| mAOD | Metres Above Ordnance Datum |
| NFCDD | National Flood and Coastal Defence Database |
| NNR | National Nature Reserve |
| PPG | Planning Policy Guidance Note |
| PAGL | Potentially Available Greenfield Land |
| PPS | Planning Policy Statement |
| RPB | Regional Planning Body |
| RPGn | Regional Planning Guidance Note |
| SAC | Special Area of Conservation |
| SFRA | Strategic Flood Risk Assessment |
| SoP | Standard of Protection |
| SPA | Special Protected Area |
| SSSI | Site of Special Scientific Interest |

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# 1.0 INTRODUCTION

## 1.1 Overview

North West Leicestershire is a largely rural area with population concentrated in the principal settlements of Coalville and Ashby de la Zouch and a number of villages including Castle Donington, Kegworth, Ibstock and Measham. Flooding is the most widespread and frequently occurring of natural hazards and, therefore, flood risk is one of many factors that should influence the spatial planning process. All forms of flooding and their impact on the natural and built environment are material planning considerations.

North West Leicestershire District Council lies wholly within the catchment of the River Trent. There is a watershed within the District at Coalville where watercourses either flow approximately north or south. The north of the District drains to the Lower Trent either directly or via the River Soar, whilst the south of the District flows via the River Mease or the River Sence to the Upper Trent. The Lower Trent is considered to be the catchment contributing to the River Trent downstream of the confluence with the River Dove in Derbyshire.

It is also important to recognise that the District of North West Leicestershire is situated immediately upstream of the Boroughs of Erewash and Rushcliffe to the North and Hinckley and Bosworth, South Derbyshire and North Warwickshire Districts to the South and West. North West Leicestershire District is adjacent to Charnwood through which the River Soar flows before entering North West Leicestershire. There are a large number of properties within the adjoining Boroughs that are susceptible to flooding from the River Trent and the River Soar, and future development within North West Leicestershire District must be carefully managed to ensure that this risk of flooding is not exacerbated.

Planning Policy Statement 25: Development and Flood Risk (PPS25)[1] states that a Strategic Flood Risk Assessment (SFRA) *"should be carried out by the local planning authority to inform the preparation of its Local Development Documents, having regard to catchment-wide flooding issues which affect the area."* In May 2007 Atkins was commissioned by North West Leicestershire District Council to develop a SFRA for the District to inform the preparation of the Core Strategy and an Allocation Development Plan Document. The preparation of the Core Strategy as part of the Local Development Framework for the District has commenced and a key aspect will be to provide a framework for the future direction of development within the District.

Leicestershire County Council is producing a Minerals Development Framework covering the County of Leicestershire and, jointly with Leicester City Council, a Waste Development Framework covering the County and Leicester City areas.

In accordance with good practice and advice from the Department of Communities and Local Government (CLG) the SFRA has considered the flood risk implications of mineral extraction and waste management development. This has included having regard to the potential sites identified by the Minerals Development Framework and Waste Development Framework within North West Leicestershire. These are sites put forward for consideration by landowners or developers and are not necessarily sites which will go forward for allocation in the Mineral and Waste Frameworks. The consideration of the flood risk implications of these sites is part of the evidence gathering required by the plan making process.

Consultation on the spatial strategies for the Minerals and Waste Development Frameworks took place in late October and November 2007. The spatial strategies

[1] Planning Policy Statement 25: Development and Flood Risk. Department for Communities and Local Government (December 2006)

do not identify individual sites for development but rather identify broad areas where minerals or waste development would be preferred. It is intended that further work will be done on site allocations for the Minerals and Waste Frameworks once the none site specific Core Strategy documents have been submitted to the Secretary of State this year. Other sites, apart form those considered in this SFRA, may come forward in future and the SFRA, along with other SFRAs covering other parts of the County and City, will be used to assess the flood risk implications of such sites. Further consultation on preferred sites for the Mineral and Waste Frameworks is programmed to take place in 2009.

## 1.2 Future Development within North West Leicestershire District

North West Leicestershire District has a long history of mineral extraction, with coal, brick clay, gravel and granite amongst the products. All the deep coal mines are now closed, but opencast continues. The District has undergone a transformation in recent years from the old employment base of deep mining to new jobs within the industrial and service sectors.

The District has good transport links through the M1, A42, A50 and A511 which can assist in further economic regeneration of the District through employment growth and new housing areas.

The North West Leicestershire Local Plan[2] sets out the planning strategy for North West Leicestershire based on the "*concentration of new development in locations on the A5111/Ivanhoe Line Corridor (i.e. Coalville, Ashby de la Zouch and Moira), but also recognises the potential for limited employment growth at the intersection of the A42 and the M1."*

A draft vision report[3] was produced in January 2007 which sets out the Vision for Coalville over the next 10 to 20 years. The report states the vision as follows:

*"Coalville is a distinctive, contemporary market town that provides a full range of retail, community and leisure services for residents and visitors and is becoming a sustainable exemplar of new development. Its convenient location and strong, positive image is recognised throughout the region and is a source of pride for the local community. An attractive and healthy place to live, work and relax".*

The report concludes that Coalville has the potential for significant growth over the next 20 years particularly in retail and leisure development but there may be a need for public sector involvement to unlock suitable sites for development. This is consistent with the emerging Regional Spatial Strategy which identifies Coalville as a sub-regional centre where there will be significant growth.

## 1.3 Objectives

The requirements for a Strategic Flood Risk Assessment are set out in PPS25 and a completed SFRA should:

- Provide sufficient data and information to enable the LPA to apply the Sequential Test to land use allocations and, where necessary, the Exception Test.

[2] North West Leicestershire Local Plan: Written Statement. North West Leicestershire District Council (Adopted 22 August 2002)
[3] Coalville Town Centre Vision (January 2007) Building Design Partnership for Donaldsons

- Enable the LPA to prepare appropriate policies for the management of flood risk within the Local Development Documents (LDDs)
- Inform the Sustainability Appraisal so that flood risk is taken into account when considering options and preparing strategic land use policies
- Identify the level of detail required for site-specific FRAs in particular locations, and
- Enable LPAs to determine the acceptability of flood risk in relation to emergency planning capability.

## 1.4 Scope of this Document

The North West Leicestershire SFRA Report has been prepared in accordance with PPS25 to summarise the findings of the data collection phase and to provide a basis for the application of the Sequential Test in respect of potential development areas/sites identified so far throughout North West Leicestershire as part of the emerging plan preparation. This SFRA covers both elements of a Level 1 and a Level 2 scope as defined in the PPS 25 Practice Guide Companion[4].

The report firstly provides an overview of the planning context in relation to flood risk and development within North West Leicestershire (Section 2). A summary of the data collected and a review of this data is provided (Section 3) which then forms a basis for the assessment of flood risk in North West Leicestershire (Section 4). The Sequential Test is outlined for each of the potential sites for development (Section 5). Sustainable flood risk management is discussed for future development in the District (Section 6) and an assessment of potential mitigation in North West Leicestershire is discussed in more detail in Section 7.

[4] Development and Flood Risk: A Practice Guide Companion to PPS25 – 'Living Draft'. Department for Communities and Local Government (February 2007)

# 2.0 REVIEW OF PLANNING POLICY

This section provides an overview of the planning context in relation to flood risk and development within North West Leicestershire.

## 2.1 National Planning Policy

National Planning Policy plays a key role in shaping the direction in which Regional Planning Boards and Local Planning Authorities (LPA) prepare their Regional Spatial Strategies (RSS) and Local Development Frameworks (LDF). Planning Policy Statements set out the Government's national policies on different aspects of land use planning in England. The key Planning Policy Statement (PPS) which has been instrumental in bringing forward SFRAs is Planning Policy Statement 25: Development and Flood Risk (PPS25). Other key PPSs which have influenced the scope of this SFRA include PPS1[5] and PPS3[6]. The key principles promoted by these PPSs are described in the following sections.

<u>PPS1: Delivering Sustainable Development</u>

PPS1 sets out the Government's aims and objectives for delivering sustainable development, for current and future generations. One of the key principles set out in PPS1 is to ensure that sustainability is considered for the life time of new development by taking due account of the physical environment and the impacts of climate change.

The key to delivering sustainable development is centred at the planning and design stages. PPS1 encourages LPAs to consider all aspects of the physical environment when identifying land for development. In particular, when preparing development plans, LPAs should identify the potential impacts that natural hazards may pose to new development and as far as possible, avoid development in areas at risk of flooding and sea level rise. Should development in areas of flood risk be required to meet the wider objectives of sustainable development, PPS1 supports the design of new development which accommodates natural hazards and the impacts of climate change to ensure the develop is safe, sustainable, durable and adaptable.

<u>PPS3: Housing</u>

PPS3 sets out the national planning policy framework for delivering the Government's housing objectives. The policies set out in PPS3 should be taken into account by LPAs and RPBs in the preparation of the Local Development Documents and RSSs. PPS3 encourages LPAs to take account of the constraints of the physical environment and natural hazards, such as flooding, when identifying broad locations for housing development.

PPS3 also states that a key objective of LPA should be to continue to make effective use of land by re-using land that has been previously developed. In addition the policy states that the national annual target is that, at least 60% of new housing, is provided on previously developed land. However, the policy also recognises that LPAs and RPBs will need to consider sustainability issues for some sites as they may not be suitable for housing. A key example of where sustainability of previously developed land may need further consideration is where land is vulnerable to flood risk.

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[5] Planning Policy Statement 1: Delivering Sustainable Development. Department for Communities and Local Government (December 2006)

[6] Planning Policy Statement 3: Housing. Department for Communities and Local Government (December 2006)

PPS25: Development and Flood Risk

PPS25 sets out the Government's polices for development and flood risk. The statement was released in December 2006 and replaces the former Planning Policy Guidance Note 25 (PPG25)[7].

The aims of PPS25 are to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new development is, exceptionally, necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and where possible, reducing flood risk overall.

PPS25 includes the same guiding principles as in PPG25, however, notably it introduces;

- A more strategic planning approach to managing flood risk.
- Stronger guidance on Flood Risk Assessments, at all stages of the planning hierarchy.
- A clarified Sequential Test.
- A new Exception Test, to account for instances where large developed areas have extensive areas within Flood Zones 2 and 3 and where a blanket ban on development would cause extensive social and economic blight.
- Clearer guidance on how to assess the impacts of climate change.

Planning Policy Statement 25: Development and Flood Risk (PPS25) complements other national planning policies and should be read in conjunction with Government policies for flood risk and water management, including Making Space for Water and the Water Framework Directive.

PPS25 requires an assessment of flood risk to be carried out to an appropriate degree at all levels of the planning process viz:-

- a Regional Flood Risk Appraisal (RFRA) to inform the Regional Spatial Strategy (RSS);
- a Strategic Flood Risk Assessment (SFRA) to inform the Local Development Documents (LDDs);
- a site-specific Flood Risk Assessment (FRA) to be submitted with planning applications for development in areas of flood risk, under the circumstances identified in the PPS;

The Planning and Compulsory Purchase Act 2004 requires that a Sustainability Appraisal is undertaken for Regional Spatial Strategies, Development Plan Documents and Supplementary Planning Documents. RPBs and LPAs are required under PPS25 to prepare and to implement planning strategies that help deliver sustainable development. In developing their policies and strategies, RPBs and LPAs should work with the Environment Agency and other relevant operating authorities and stakeholders in appraising, managing and reducing flood risk. As part of this process, RPBs should prepare Regional Flood Risk Appraisals (RFAs) and LPAs should prepare Strategic Flood Risk Assessments (SFRAs) as freestanding assessments to contribute to the Sustainability Appraisal of their plans.

## 2.2 Regional Planning Policy

Regional Planning Guidance for the East Midlands (RPG8) was published by the Government in January 2002. A selective review was carried out, with consultation up

[7] Planning Policy Guidance Note: Development and Flood Risk. DETR (2001)

to 30 June 2003. Following the enactment of the Planning & Compulsory Purchase Act 2004 Regional Planning Guidance became part of the statutory development plan and has been re-named as a Regional Spatial Strategy (RSS). RPG8 therefore becomes RSS8 and was approved in March 2005.

The Regional Spatial Strategy is the broad development framework for the region up to 2021. It is the spatial element of the Integrated Regional Strategy which also embraces the region's economic, environmental and social strategies.

There are also sub-regional policies covering five sub areas of which the Three Cities Sub-area (Derby, Nottingham, Leicester) covers North West Leicestershire.

Policy 36 - A Regional Approach to Managing Flood Risk of the RSS states that:

*"The Development Plans, future Local Development Frameworks, and strategies of relevant agencies should:*

- *be informed by the use of appropriate Strategic Flood Risk Assessments in order to evaluate actual flood risk and should include policies which prevent inappropriate development either in, or where there would be an adverse impact on, the fluvial floodplain areas;*
- *deliver a programme of flood management schemes that also maximise biodiversity and other regeneration benefits; and*
- *require sustainable drainage in all new developments where practicable. Development should not be permitted if, alone or in conjunction with other new development, it would:*
    - *be at unacceptable risk from flooding or create such an unacceptable risk elsewhere;*
    - *inhibit the capacity of the floodplain to store water;*
    - *impede the flow of floodwater;*
    - *have a detrimental impact upon ground water storage capacity;*
    - *otherwise unacceptably increase flood risk; and*
    - *interfere with coastal processes.*

*However, such development may be acceptable on the basis of conditions or agreements for adequate measures to mitigate the effects on the overall flooding regime, including provision for the maintenance and enhancement (where appropriate) of biodiversity. Any such measures must accord with the flood management regime for that location. Strategic flood risk assessments should be carried out where appropriate to inform the implementation of this policy."*

The RSS is currently undergoing a revision which rolls forward the period covered by the RSS up to 2026 and amongst other matters also provides for district level housing figures. The review of the RSS includes:

- housing provision figures
- the target for new housing built on previously-developed land (60 per cent)
- the sequential approach to encourage sustainable development
- affordable housing

Following the issue of proposed changes by the Secretary of State in Summer 2008, and subsequent public consultation, the RSS is expected to be published in its final form. The emerging RSS is likely to be adopted in time for the emerging Local Development Framework.

## 2.3 Local Planning Policy

### 2.3.1 Leicestershire, Leicester and Rutland Structure Plan

The Leicestershire, Leicester and Rutland Structure Plan 1996 - 2016 was adopted in March 2005. The Plan was prepared jointly by Leicestershire County Council, Leicester City Council and Rutland County Council. It provides a strategic planning framework for development and use of land consistent with national and regional policy. The Plan provides a guide to the detailed policies and proposals of Local Development Frameworks and decisions on planning applications. The plan covers housing and employment needs as well as the provision of new roads, green spaces for recreation and leisure, mining and disposal of waste.

Within the Structure Plan there are 3 policies which are relevant to flood risk, as follows:

<u>Strategy Policy 2B – Suitability of land for development</u>

In considering the suitability of land within the context of a sequential approach the following criteria will be taken into account:

- *"Physical constraints on development, including ground contamination and stability and flood risk"*

<u>Strategy Policy 17 – Strategic River Corridors</u>

*"The strategic importance for flood relief and biodiversity of the Rivers Soar, Trent, Welland, Wreake, Chater, Gwash, Mease, Eye, Sence (eastern) and Sence (western) and their floodplains will be recognised. Measures will be taken along these corridors through an integrated approach to protect and enhance:*

*a. Their capacity to function as natural floodplains;*
*b. Their linear continuity in the interests of biodiversity; and*
*c. The form, local character and distinctiveness of the natural, historic and built environment".*

<u>Resource Management Policy 4 – The Water Environment</u>

*"Development will only be acceptable:*

*a. If measures to maximise efficient use of water, including grey water, have been taken into account;*
*b. Where it will not have an unacceptable impact on the source of the water supply, the supply of water for navigation, or the role of the natural watercourse system for providing essential drainage of land, valuable wildlife environments and amenity areas;*
*c. In locations where adequate water resources exist, or where resources can be provided in a sustainable manner;*
*d. If surface water run-off is minimised by incorporating and maintaining sustainable drainage systems or retention systems, where appropriate.*

*Development will not be acceptable if it would be at unacceptable risk from flooding or, if alone or together with existing and committed development, it would increase the risk of flooding elsewhere, unless provision is made for adequate measures to mitigate the effects on the flooding regime".*

*The only policies saved in the Structure Plan relate to overall housing numbers and an aim for 50% of new development to be on previously developed land.*

### 2.3.2 Leicestershire Minerals Development Framework

Leicestershire County Council is preparing a Minerals Development Framework to plan for the future provision of minerals in the County excluding Leicester City. Within the Core Strategy and Development Control Policies Preferred Options document July 2006 there is a policy relating to flood risk.

Policy 34 – The Water Environment

*"Planning permission will not be granted for minerals development which would:*

*(i). Have a detrimental impact on the quality or flow of groundwater or surface water drainage; or*
*(ii). Exacerbate flood risk in areas prone to flooding and elsewhere".*

### 2.3.3 Leicestershire and Leicester Waste Development Framework

Leicestershire County Council is preparing a Waste Development Framework to set out how facilities for the management of waste produced in the County will be catered for. Within the Core Strategy and Development Control Policies Preferred Options document July 2006 there is a policy relating to flood risk.

Policy 26: The Water Environment

*"Planning permission will not be granted for waste management development which would:*

*(i) have a detrimental impact on the quality or flow of groundwater or surface water drainage, or*
*(ii) exacerbate flood risk in areas prone to flooding and elsewhere".*

### 2.3.4 North West Leicestershire Local Plan

The North West Leicestershire District Local Plan was adopted in August 2002. The Local Plan sets out the policies and proposals for future development and land use within North West Leicestershire and forms part of the North West Leicestershire Local Development Framework.

The stated end date of the plan was 2006 but in accordance with the Planning and Compulsory Purchase Act 2004 a number of policies have been saved until such time as they are replaced by new policies in the Local Development Framework. Amongst these policies saved the following are of relevance in respect of flooding matters.

Policy E30 – Natural Watercourses

*"Development will not be permitted which would increase the risk of flooding and remove the extra discharge capacity from the floodplains of either Black Brook and Gilwiskaw Brook or of the River Mease, Soar or River Trent, unless as part of the development the developer provides appropriate measures to protect the land from such effects".*

Policy H4/1 – Housing Land Release Policy

The Local Plan states that in selecting sites LPAs should assess their potential and suitability for development against:

*"The physical and environmental constraints on development of land, including, for example, the level of contamination, stability and flood risk, taking into account that such risk may increase as a result of climate change".*

Policy T5 – Road Related Development

Development of road-related service facility will only be permitted provided:

*"Satisfactory measures can be undertaken to compensate for any detrimental effect on the floodplain of the River Trent".*

Policy L12 – Leisure and Tourism

The Local Plan states that tourism and recreation uses will be permitted on land south of Sawley Marina provided the development proposed *"Incorporates necessary measures to protect the flood storage capacity of the site."*

Policy J3 – Employment Storage and Distribution

The site of Castle Donington Power Station is allocated for the development of a Regional Storage and Distribution Centre. The Local Plan states that development of this site must be undertaken in a comprehensive manner and *"satisfactory compensatory measures must be provided to alleviate the impact of development on the flood plain of the River Trent".*

### 2.3.5 North West Leicestershire Local Development Framework

The Core Strategy Development Plan Document will, once adopted, set out the vision, strategic objectives and spatial strategy for future developments within North West Leicestershire.

An Issues and Options Consultation was undertaken in November 2005 and states that any new development should take into consideration the physical constraints on the development of land including the level of flood risk. The plan also refers to Policy 35 of the RSS in relation to maintenance and enhancement of the strategic river corridors within North West Leicestershire.

# 3.0 DATA COLLECTION AND REVIEW

## 3.1 Introduction

The purpose of the data collection and review phase of the SFRA is to identify and obtain information regarding flood risk. It is during this phase that existing knowledge is collated with regards to the sources and extent of flood risk; existing flood management measures; and the land use and development opportunities within the North West Leicestershire area.

Consultations have been undertaken with North West Leicestershire District Council, Leicestershire County Council, the Environment Agency, British Waterways, Severn Trent Water, the Coal Authoirty and neighbouring authorities.

The information gathered during this phase has been used to assess the potential extent and frequency of flood risk, the implications of this flood risk for development opportunities and the opportunities for flood management practices which may help mitigate or reduce future flood risk.

## 3.2 Overview of the District Area

North West Leicestershire District covers an area of approximately $280km^2$ and is situated within the Trent catchment. Within any catchment the hydrology is intrinsically linked to the geology and topography. The geology of the District is dominated by Triassic Mercia Mudstone which is relatively soft and has been eroded over thousands of years to form the wide flat valleys of the River Trent and the River Soar which bound the North and East of the District.

Carboniferous Coal Measures underlie much of the South of the District and forms part of the Leicestershire and South Derbyshire Coalfield. The Coalfield consists of a northern section where the Lower, Middle and Upper Carboniferous Coal Measures are exposed, and a southern section where they are beneath Mercia Mudstone and Sherwood Sandstone which, in turn, are overlain by glacial till.

The coalfield landform is one of gentle ridges and shallow valleys. The undulations become particularly shallow towards the south where there are locally thick deposits of glacial till which form the Mease/Sence Lowlands and the Leicestershire Vales. To the north the land falls away, often quite steeply, to the River Trent. The coalfield forms part of the watershed between the Mease and Sence to the south and the Soar to the east, with numerous brooks draining the generally undulating land.

Geology has a very strong influence on a catchments response to rainfall. The degree to which water can percolate through rock, the permeability, influences the extent of overland flow and therefore the response of a watercourse to a rainfall event. The Mercia Mudstone has high clay content and is relatively impermeable resulting in rapid surface runoff. The Sherwood Sandstone and Coal Measures, whilst more permeable, can promote rapid surface runoff where they form steep slopes.

Historically, the watercourses in the District have experienced many man-made changes, particularly where mining has been carried out. This has disturbed the natural processes of erosion and accretion and increased sediment movement, resulting in localised flooding from culvert, sluice gates and channel blockages. Farming practices and land use affect soil structure and vegetation cover and can impact on run-off rates and soil erosion. From the elevated area around Coalville a number of small fast flowing streams transfer sediment into the relatively flat River Soar. This river requires regular silt removal, carried out by British Waterways, to maintain the channel capacity and allow navigation.

Topography provides the basis to assess the accuracy of predicted flood zone extents where detailed hydraulic modelling or historical flood outlines are not readily available. It is important to ensure that the Environment Agency Flood Zone Map reflects the topography. LiDAR data, provided by the Environment Agency along with OS Contour Maps have been used to reflect the topography of the District.

## 3.3 Flood Zone Definition

### 3.3.1 PPS25 Flood Zones

PPS25 identifies 4 separate Flood Zones which should be used when determining the appropriateness of proposed development uses when considering flood risk through the application of the Sequential Test. These Flood Zones represent flooding without flood defences in place.

Tables D1 Flood Zones and D2 Flood Risk Vulnerability Classification within Annex D of PPS25 respectively define these Flood Zones and describe the appropriate land use vulnerabilities for each zone. A summary of each Flood Zone and land use is provided below and supported by Table 1.

***Table 1 – Appropriate Development for each Flood Zone (based on Table D3 of PPS25)***

| Flood Risk Vulnerability Classification (see Table D2 of PPS25) | | Essential Infrastructure | Water Compatible | Highly Vulnerable | More Vulnerable | Less Vulnerable |
|---|---|---|---|---|---|---|
| Flood Zone (see Table D1 of PPS25) | Zone1 Low Probability | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Zone2 Medium Probability | ✓ | ✓ | Exception Test required | ✓ | ✓ |
| | Zone 3a High Probability | Exception Test required | ✓ | x | Exception Test required | ✓ |
| | Zone 3b 'Functional Floodplain' | Exception Test required | ✓ | x | x | x |

✓ Development is appropriate
*X* Development should not be permitted

Flood Zone 1 is defined as having a 'Low Probability' of flooding and incorporates areas where the annual probability of flooding is lower than 0.1% (or 1 in 1000 year return period flood event). PPS 25 imposes no constraints upon the type of development within Flood Zone 1.

Flood Zone 2 is defined as 'Medium Probability' with an annual probability of flooding between 0.1% and 1.0% (or between 1 in 1000 and 1 in 100 year return period flood event) for fluvial and 0.1 and 0.5% (or between 1 in 1000 and 1 in 200 year return period flood event) for tidal and coastal flooding. PPS 25 recommends that Flood Zone 2 is suitable for most types of development with the exception of Highly Vulnerable uses, as defined within Table D.2 of PPS25.

Flood Zone 3 is defined as 'High Probability' with an annual probability of flooding of 1.0% (or 1 in 100 year return period flood event) or greater for fluvial and 0.5% (or 1 in 200 year return period flood event) and greater for tidal or coastal. PPS 25 recommends that appropriate development is based upon a further classification of Flood Zone 3 into: 3a High Probability and 3b Functional Floodplain (where water has to flow or be stored in times of flood). Greater constraints are placed upon development within Flood Zone 3; refer to Table 1 for details.

### 3.3.2 Environment Agency Flood Map

The Environment Agency's Flood Map was published on the Internet in October 2004. The Flood Map is the Environment Agency's current best estimate of the undefended 1% annual exceedance probability (AEP) (or 1 in 100 year return period flood event) and 0.1% AEP (or 1 in 1000 year return period flood event) fluvial floodplain and 0.5% AEP (or 1 in 200 year return period flood event) and 0.1% AEP (or 1 in 1000 year return period flood event) tidal floodplain.

The Flood Map outlines have been derived using a combination of a generalised model derived as part of the Flood Zone Project (a high level national mapping programme), more detailed hydraulic modelling and historical flooding outlines. The Flood Map outlines, therefore, have a varying degree of accuracy dependent on the quality of the inputs and, in particular, the availability of detailed hydraulic modelling. The Flood Map is updated on a quarterly basis as the Environment Agency's knowledge of flooding is improved through detailed modelling studies, recent flood events and data from river level and flow monitoring stations.

The Flood Map presents flood risk in accordance with the PPS25 Flood Zones 1, 2 and 3a. Figure A1 within Appendix A displays the existing Environment Agency Flood Maps for Zones 2 and 3.

## 3.4 Hydraulic Modelling

A number of flood risk mapping studies have been carried out by the Environment Agency across North West Leicestershire District. These studies have involved the development of detailed hydraulic models, providing a more robust understanding of the local flooding mechanisms and flow paths. These studies have been carried out in accordance with Section 105 (2) of the Water Resources Act and the 1% AEP modelled outline is shown in Figure A1 in Appendix A.

Watercourses for which detailed hydraulic modelling has been undertaken include the River Trent, Grace Dieu Brook, Black Brook, River Mease, Gilwiskaw Brook and Hooborough Brook. The River Soar has also been modelled as part of a recent strategic study; however flood outlines are not available.

The hydraulic modelling is based on detailed cross sectional survey and hydrological assessment and the mapping of the flood levels is based on a detailed Digital Terrain Model. Therefore, the flood extents derived from the detailed hydraulic modelling are considered to be more accurate than the Flood Map which is derived from a National Generalised Model which cannot fully represent complexities in flood flow routes.

The hydraulic model outlines for the 1% AEP and 0.1% AEP have been compared with the Flood Map to derive definitive flood outlines for Zone 2 and Zone 3a which are used as the basis of the sequential test. In the absence of site-specific information to the contrary, functional floodplain is assumed to be land which would flood with an annual probability of 1 in 20 or greater in any one year (5% AEP) as stated in PPS25 or land which is set aside for flood storage. None of the hydraulic models have been run for a 5% AEP; however, there are flood outlines available for a 4% AEP (1 in 25 year return period). The 4% AEP flood outline has been used to represent the functional floodplain as this is considered to be the best available information.

## 3.5 Historical Flood Events

Information on historical flood events can supplement our understanding of flooding mechanisms and flood extents. Post event reports and flood chronologies indicate that the most recent significant flood events to affect the whole of the Trent basin occurred in 1932, 1947, 1960, 1998 and 2000. Individual catchments have also experienced severe flooding at other times.

Trent/Soar

The 1947 event was caused by snowmelt following prolonged rainfall and affected many locations in England and Wales. The event was notable for its prolonged duration and significant flood volumes. This event remains the highest recorded at several locations on the River Soar and Lower Trent. In recent years, the largest events on the Lower Trent were in Autumn 1998 and October/November 2000. However, the Easter 1998 event was significant on the River Soar.

In the Autumn 1998 event there was flooding of the lower Soar with the 10% AEP defences at Kegworth overtopped. However, the 1% AEP defences at Ratcliffe on Soar were not breached or overtopped.

The October/November 2000 floods had a widespread impact throughout the Trent catchment with an approximate AEP of between 4% and 2%. The worst affected areas were the lower reaches of the River Soar and the middle reaches of the Trent from upstream of Nottingham to Newark both affecting property within North West Leicestershire. Environment Agency defences failed or were overtopped along the River Soar. No properties flooded between Kegworth and the River Trent confluence from the Soar; however there were a significant number of properties flooded within North West Leicestershire, including:

- Burton to Castle Donington – 18 properties flooded from the River Trent and received a severe flood warning
- Castle Donington to Long Eaton – 6 properties flooded from the River Trent and received a severe flood warning
- Cotes to Kegworth – 15 properties flooded from the River Soar and received a flood warning; 13 properties not flooded but received a flood warning.

The River Soar suffered severe flooding in 1932 and 1954 which led to the construction of flood management schemes in the 1960s mainly through Leicester. However, there are still considerable areas at risk of flooding from the Soar and a strategy study has been undertaken recently for future flood risk management of the reach from Sharnford to the Trent confluence.

Grace Dieu Brook

There has been significant flooding of roads and properties from Grace Dieu Brook, for example in Thringstone and Belton in 1987. Flooding of roads and property also occurred in 1955 in the village of Osgathorpe from Grace Dieu Brook.

The most significant event recently was in July 2002 when 105mm of precipitation was recorded at Mount St. Bernards raingauge over a 9 hour period. This rainfall is 91% more than the monthly average for July and equates to about one seventh of the average annual precipitation recorded at the gauge. The rainfall resulted in an extreme event on Black Brook and Grace Dieu Brook and there was significant flooding with the residents of 58 properties requesting assistance from North West Leicestershire District Council to remove flood damaged household items. There was also significant flooding of roads which resulted in major disruption to residents of Whitwick. Many other properties along the course of the Brook suffered damage to their gardens.

Gilwiskaw Brook

Significant flooding of roads has occurred in Packington and Ashby de la Zouch from Gilwiskaw Brook. 1 property and 5 gardens were flooded following heavy rainfall in July 2001. The flooding of Mill Street during the July 2001 event cause disruption to the residents of Packinton. Several other heavy rainfall events have resulted in flooding of roads and gardens in Packington with the most recent events in June 2007.

Minor Watercourses

Flooding occurs frequently in Hemington Village from Hemington Brook. In February 1977, 9 houses, a post office, 2 public houses and a road were flooded. The cause of flooding is the inadequate capacity of brook, culverts and access bridges. Hemington Brook is affected by backing up from the Rivers Soar and Trent.

Flooding of roads and properties has been reported in Lockington caused by the inadequate capacity of Lockington Brook and the culvert in the centre of the village.

Other reported flooding includes houses and the road in Hallgate and Ladygate in Diseworth from Diseworth Brook and Hall Brook which carry runoff from Nottingham East Midlands Airport and flooding of an access road from B5401 in Long Whatton from Long Whatton Brook. However, these are thought to be the result of local issues regarding channel maintenance.

Historical Flood Outlines

Historic digital spatial flood data is available from the Environment Agency for several watercourses within North West Leicestershire. The historic flood outline is shown in Figure A1 in Appendix A with the study watercourses highlighted. It can be seen that flooding is known to occur in the lower reaches of the Black Brook from downstream of its confluence with the Grace Dieu (possibly due to backing up from the River Soar), and also along the wide floodplain of the River Soar and River Trent. In addition, there is a historical flooding outline for the River Mease.

## 3.6 Recent Studies on Flood Risk

Several studies have been undertaken within the Trent catchment which have a relevance to the North West Leicestershire SFRA. There are four main studies that are relevant to this SFRA.

The Black Brook Strategic Flood Risk Mapping (SFRM) Study (Capita Symonds, Dec 2006) delineated the flood risk along Black Brook and its main tributary, the Grace Dieu watercourse. The outputs of this study are flood risk outlines for a range of return periods.

The Fluvial Trent Strategy Report (Environment Agency, March 2005) considers the entire fluvial length of the River Trent and recommends strategies for alleviating flood risk at a number of locations. The report covers the stretch of the River Trent from Stoke on Trent to Newark on Trent. Consideration is also given to the major tributaries in the catchment, such as the River Soar, which forms part of the eastern border of North West Leicestershire.

The Trent Catchment Flood Management (CFMP) Study (Environment Agency, October 2007) considers flood risk issues on a catchment wide basis and identifies opportunities and constraints for future flood risk management within the Trent catchment. The CFMP has identified policies for future flood risk management and provides an action plan outlining how this will be carried out.

The Lower Trent Flood Warning Management Plan (Atkins, Jan 2006) considers improvements to the current flood warning system in order to meet the Making it Happen targets. The plan covers the Lower Trent and the River Soar and outlines the priorities for improvements and extensions to the Flood Warning Service whilst investigating the technical feasibility of options.

These studies have been used to inform the SFRA through the understanding of flood risk issues, the provision of flood outlines and future flood risk management opportunities in North West Leicestershire.

## 3.7 Existing Flood Defences

### 3.7.1 Definition of a Flood Defence

Information on flood defences is required to indicate areas where there is protection from fluvial flood risk, the level of protection provided by the defence and the predicted life of the defence.

Flood defences are raised structures which prevent floodwater from flooding surrounding areas by altering the natural flood flow paths from a watercourse or retaining flood water. Flood defences are categorised as ‘formal’ defences or ‘informal’ defences. A ‘formal’ defence is a structure that was built specifically to defend land or property from flooding and is maintained for this purpose by the Environment Agency, Local Authority, or a riparian landowner. An ‘informal’ defence is a structure that has not been specifically built to retain floodwater and is not maintained for this specific purpose but may afford some protection against flooding. ‘Informal’ defences include boundary walls, industrial buildings and railway and road embankments.

The extent, condition and standard of protection of the defences owned and maintained by the Environment Agency are recorded within the National Flood and Coastal Defence Database (NFCDD).

To determine the standard of protection provided by the defence, the following information is essential:

- Location of defence
- Defence Crest Level

Where available the following information was also collated;

- Condition of the defence (based on the NFCDD scale and measured between 1 and 5 Good – Poor)
- Residual life
- Type of defence

### 3.7.2 Location and Description of Flood Defences

The 1947 flood event, the most severe event in the last century, acted as a catalyst for the construction of the present flood defences throughout the Trent catchment. Flood defence embankments are in place along the River Trent and the River Soar where the rivers form the northern and eastern parts of the North West Leicestershire District boundary. The flood defences were constructed in the 1960s and early 1970s and at the time provided protection from flooding with an annual probability of up to 1%.

The main areas for flood defences along the River Trent are Cavendish Bridge, a large stretch of the eastern side of the M1 and Trentlock, at the confluence with the River Soar.

The River Soar has two sets of embankments. The first are small raised earth embankments set close to the river (within 10 metres), to protect farmland against frequent flooding. The second much larger embankments are designed to protect inhabited areas and are generally set much further away from the river. This arrangement provides extensive areas of flood storage on the floodplain, whilst protecting the many villages and towns in the area.

There are formal defences along Gilwiskaw Brook, Hemington Brook, Lockington Brook and Grace Dieu Brook ranging from a standard of protection of 10% AEP to 2% AEP. Table 2 and Figure A2 in Appendix A shows the location and standard of protection of these defences along with those on the Trent and the Soar.

In addition to the formal defences there are numerous informal defences in private ownership, for example on Grace Dieu Brook and Gilwiskaw Brook, where responsibility for maintenance lies with the riparian owners and the standard of protection and maintenance regimes are unknown.

***Table 2 – Raised Defences (based on NFCDD)***

| Asset Type | Maintainer | Asset Description | Asset Location | Design SoP (yrs) | Watercourse | Protecting |
|---|---|---|---|---|---|---|
| raised defence (man-made) | private | Old Road Bridge Abutment | Old Packington Road Bridge | 50 | Gilwiskaw Brook | Farm land |
| raised defence (man-made) | Environment Agency | Floodbank | Trent confluence to opposite bungalow | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | Opposite Kenwood bungalow to start of Cut | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | Cut at Redhill to penstock | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | U/s of Lockington Park | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | From piled bank to sluice Redhill | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | U/s Redhill Marina | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | Ratcliffe-on-Soar | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | U/s of Ratcliffe Lock | 10 | Soar | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | Ratcliffe to Kingston Brook | 10 | Soar | Farm land and Isolated properties |

*Table 2 – Raised Defences (based on NFCDD) cont'd*

| Asset Type | Maintainer | Asset Description | Asset Location | Design SoP (yrs) | Watercourse | Protecting |
|---|---|---|---|---|---|---|
| raised defence (man-made) | Environment Agency | Floodbank | Kegworth | 10 | Soar | Properties in Kegworth |
| raised defence (man-made) | Environment Agency | Floodbank | Bridge Farm | 100 | Soar | Bridge Farm and Properties in Kegworth |
| raised defence (man-made) | Environment Agency | Floodbank | Bridgefields, Kegworth | 10 | Soar | Properties in Kegworth |
| raised defence (man-made) | Environment Agency | Floodbank | Station Rd, Kegworth to u/s Kegworth Br. | 10 | Soar | Properties in Kegworth |
| raised defence (man-made) | private | Embankment. | Dismantled railway | 25* | Grace Dieu Brook | Farm land |
| raised defence (man-made) | private | Embankment | U/s of Ashby Road | 25* | Grace Dieu Brook | Farm land |
| raised defence (man-made) | local authority | Railway embankment. | D/s of the City of Three Waters. | 25* | Grace Dieu Brook | Properties in Whitwick |
| raised defence (man-made) | local authority | Embankment | D/s of Coverdale | 25* | Grace Dieu Brook | Properties in Whitwick |
| raised defence (man-made) | local authority | Raised wall. | Coverdale. | 25* | Grace Dieu Brook | Properties in Whitwick |
| raised defence (man-made) | Environment Agency | Embankment. | A50, Lockington. | 25* | Lockington Brook | Farm land and Isolated properties |
| raised defence (man-made) | private | Embankment. | U/S of A50, nr Lockington. | 25* | Lockington Brook | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Wall | Lockington | 25* | Lockington Brook | Properties in Lockington |
| raised defence (man-made) | Environment Agency | Embankment. | Along the M1. | 25* | Hemington Brook | Farm land and Isolated properties |
| raised defence (man-made) | Environment Agency | Floodbank | Sewley Lock d/s | 10 | Trent | Farm land and Isolated properties |
| raised defence (man-made) | private | Earth Bank | D/s Trent / A6 crossing | 100 | Trent | Properties in Castle Donington |

** Standard of Protection of Defences estimated*

***Table 2 – Raised Defences (based on NFCDD) cont'd***

| Asset Type | Maintainer | Asset Description | Asset Location | Design SoP (yrs) | Watercourse | Protecting |
|---|---|---|---|---|---|---|
| raised defence (man-made) | Environment Agency | Earth Bank | D/s Trent / A6 crossing | 10 | Trent | Properties in Castle Donington |
| raised defence (man-made) | private | Earth Bank | D/s Trent / A6 crossing | 10 | Trent | Properties in Castle Donington |
| raised defence (man-made) | Environment Agency | Earth Bank | D/s Trent / A6 crossing | 100 | Trent | Properties in Castle Donington |
| raised defence (man-made) | Environment Agency | Earth Bank | U/s Trent / A6 crossing | 100 | Trent | Properties in Castle Donington |
| raised defence (man-made) | private | Earth Bank | U/s Trent / A6 crossing | 10 | Trent | Properties in Castle Donington |

## 3.8 Flood Warning

In addition to flood defences to reduce the probability of flooding, flood warning has been in operation in the Trent catchment for a number of years as a means of reducing the impacts of flooding. A range of systems have been in operation in various parts of the catchment operated by the Environment Agency and their predecessors, the National Rivers Authority, the Water Authorities and even as far back as the River Boards during the early 1960s. Although flooding in the upper parts of the catchment is difficult to predict because of the rapid response of the smaller and urbanised catchments, the lower reaches of the Trent can benefit from relatively accurate forecasts with good lead-times based on upstream water levels.

There are several flood warning services currently provided for areas at risk of flooding within North West Leicestershire, these include:

- River Mease - Gilwiskaw Brook from Packington to Clifton Campville
- River Soar from Cotes to Kegworth (Village of Cotes, east of Loughborough where the A60 crosses the river to the village of Kegworth close to junction 24 of the M1 including Zouch)
- River Soar from Kegworth to Redhill (Kegworth near to junction 24 of the M1 to the confluence of the River Soar with the River Trent at Redhill including Ratcliffe on Soar)
- River Trent at Castle Donington

The above Flood Warning Areas are based on the Extreme Flood Outline. The Extreme Flood Outline contains data on historic flooding. This is because some known historic flooding has occurred outside of Flood Zone 2.

In addition to the above Flood Warning Areas, North West Leicestershire is covered by general early alerts to possible flooding, known as Flood Watches, these include:

- River Mease (Ashby to Croxall)
- River Sence in Leicestershire (River Sence and tributaries from Billesdon to the River Soar at Glen Parva)
- River Soar in Leicestershire (River Soar and tributaries from Sharnford to the River Trent at Thrumpton Park)

- River Trent in Nottinghamshire (River Trent and tributaries in Nottinghamshire from Castle Donington to Cromwell Weir)

## 3.9 Development Control

North West Leicestershire District Council and the Environment Agency have staff dedicated to the control of development within North West Leicestershire

The Town and Country Planning System is designed to regulate the development and use of land in the public interest. It is the means by which the environment can be enhanced and protected whilst enabling development to take place which is necessary for economic and social well-being. North West Leicestershire District Council's Development Control seeks to ensure the aims of the Town and Country Planning System are achieved through the submission and determination of applications for planning permission for development

The North West Leicestershire Core Strategy Development Plan Document will, once adopted, set out the vision, strategic objectives and spatial strategy for future developments within North West Leicestershire. Development Control Policies are a suite of criteria-based policies which are required to ensure that all development within the areas meets the spatial vision and spatial objectives set out in the *Core Strategy*. These Development Control policies will include policies for development within floodplains and will be incorporated into the Core Strategy.

The Environment Agency has a role in advising the town and country planning process and will object to inappropriate development within areas at risk of flooding. If planners are minded to go against Environment Agency advice and approve proposed development, they are required to refer the proposal to the Secretary of State[8]. This only applies to 'major developments' which are defined as a development where the number of dwellings to be constructed is 10 or more and/or the site area is 0.5 hectares. For all other uses, a major development is one where the floorspace to be built is 1000 square metres or more, or where the site area is 1 hectare or more.

The Environment Agency has direct control over activities that may affect watercourses and the floodplain. According to the Water Resources Act 1991 and local byelaws, anyone wishing to carry out work in, over, under or within 8 metres from the top of bank of a main river, or 5 metres from an Internal Drainage Board watercourse needs consent from the Environment Agency. Under the Land Drainage Act 1991 and byelaws, any proposal to construct works within any other watercourse also needs Environment Agency consent if they relate to culverting or structures that resemble a mill, dam, weir or other like obstruction.

The Environment Agency's Development Control teams support the planning system through the provision of advice and information on flood risk to planning authorities and developers to enable full compliance with PPS25.

## 3.10 Emergency Planning

*Emergency planning is about having in place arrangements and adequately trained personnel to ensure an effective response to any event or situation, which threatens serious damage to human welfare or the environment or threatens the security of the community*[9].

Leicester, Leicestershire and Rutland Local Resilience Forum is responsible for developing emergency plans and does so in close liaison with its partner agencies.

[8] Town and Country Planning (Flooding) England Direction, 2007
[9] Leicester, Leicestershire and Rutland Local Resilience Forum Website (February 2008)

A Community Risk Register has been has been compiled by members of the Local Resilience Forum to identify the hazards, risks and threats which may be present. Its aim is to deliver a risk awareness framework which will improve the ability to prevent and plan for emergencies. The local risks of relevance to this SFRA are:

- Major Flooding - Flooding of homes; evacuation of people; accommodation required for evacuees

- Major/Severe Flash Flooding - Duration probably <1 days; flooding of homes; evacuation of people; accommodation required for evacuees

The purpose of the Community Risk Register is:

- *To ensure that local responders have an accurate understanding of the risks that they face and to provide a sound foundation for planning*
- *To provide a rational basis for the prioritisation of objectives, work programmes and allocation of resources*
- *To enable local responders to assess the adequacy of their plans and identify any gaps*
- *To facilitate joined up planning, based on consistent planning assumptions*
- *To provide an accessible overview of the emergency planning context for the public and officials*
- *To inform and reflect on national and regional risk assessments that support emergency planning and capability development at those levels*[7]

Partner agencies are either Category 1 or Category 2 responders. For a major flood event in North West Leicestershire the Category 1 responder is any body in the UK that has specific duties as determined under the Civil Contingencies Act (2004) and includes:

- Local Authority – North West Leicestershire District
- Government Agency – Environment Agency
- Emergency Services - Leicestershire Constabulary, Leicestershire Fire & Rescue Service, East Midlands Ambulance Service NHS Trust
- Health Bodies - Health Protection Agency, Leicestershire Partnership NHS Trust

For a major flood event in North West Leicestershire the Category 2 responders are those who have a role in supporting Category 1 responders in their duties under the Civil Contingencies Act (2004) and include:

- Utilities – Electricity, Gas, Water and sewerage, public communications providers (landlines and mobiles)
- Transport - Network Rail, Train Operating Companies, Airports, Highways Agency
- Government - Health and Safety Executive
- Health Sector - Strategic Health Authority

## 3.11 Land Allocations

Information on land allocations within North West Leicestershire have been obtained from a number of sources, as follows:

- North West Leicestershire's Local Plan
- Urban Housing Potential Study[10]
- Leicestershire Minerals Development Framework[11]
- Leicestershire Waste Development Framework[12]

[10] Urban Housing Potential Study. North West Leicestershire District Council. Final Report, April 2005.
[11] Leicestershire Minerals Development Framework, Site Allocations, Preferred Options (up to 2021) Leicestershire County Council, July 2006.

The Local Plan outlines land allocations for housing and employment whilst the Urban Housing Potential Study identifies housing potential from the 'Main Towns' of Coalville and Ashby-de-la-Zouch, and the smaller settlements of Measham, Ibstock, Castle Donington and Kegworth. The Urban Housing Potential Study has identified a number of sites with potential for housing development. Preferred waste and mineral sites have been identified within the Leicestershire Minerals and Waste Development Frameworks.

The location of all of these potential development sites is shown on Figure 3 of Appendix A.

## 3.12 Consultation

### 3.12.1 North West Leicestershire District Council

The planning department have been consulted to identify areas under pressure from development and the sites which have been allocated for potential development. The council have also been consulted on their role in emergency planning and their responsibilities as a Category 1 Responder under the Civil Contingencies Act 2004.

### 3.12.2 Leicestershire County Council

Leicestershire County Council has been consulted on sites allocated for mineral and waste uses. Consultation has also been undertaken with staff from highway drainage and emergency planning.

### 3.12.3 Environment Agency

North West Leicestershire District spans across two Environment Agency Areas, Central and Eastern Areas of Midlands Region. Both areas have been consulted to obtain information on sources of flood risk, hydraulic modelling, flood defences and flood warning as well as to discuss future sustainable flood risk management and mitigation measures.

### 3.12.4 Severn Trent Water

Severn Trent Water have been consulted to obtain information on the number of recorded incidences of sewer flooding. Information was only provided as a summary of the number of recorded incidents by post code area so it was difficult to pinpoint any known capacity problems or infrastructure at risk of failure.

### 3.12.5 British Waterways

British Waterways, who are responsible for navigable sections of the River Trent and the River Soar where it borders North West Leicestershire and for the Ashby Canal, have been consulted to obtain information on historical flooding or any critical structures which may be at risk of failure.

### 3.12.6 Coal Authority

The Coal Authority was established in Parliament in 1994 to undertake specific statutory responsibilities with past and present coal mining activities. Of particular

[12] Leicestershire and Leicester Waste Development Framework, Site Allocations (Preferred Options) up to 2021, Leicestershire County Council, July 2006.

relevance to North West Leicestershire is the Coal Authority's responsibility for historic liabilities within the Leicestershire and South Derbyshire coalfield including issues with minewater discharge and minewater rebound. The Coal Authority have been consulted on groundwater trends following the closure of the mines.

### 3.12.7 Neighbouring Planning Authorities

Neighbouring planning authorities have been consulted to identify potential upstream developments that are likely to cause increased flood risk to the North West Leicestershire District. Similarly, areas downstream of North West Leicestershire have been consulted as they may be affected by policies within North West Leicestershire.

Although the District of North West Leicestershire has boundaries with 6 other local planning authorities the impact of developments within these areas on flood risk through North West Leicestershire is minimal. The reason for this is that North West Leicestershire lies mainly in the upper catchments of tributaries which drain to the River Trent. The only watercourses draining from other planning authorities into North West Leicestershire are the River Trent and the River Soar which provide the northern and eastern boundaries of the District respectively.

**Upstream Authorities**
The local planning authority of Charnwood is situated to the east of North West Leicestershire and development within this authority could impact on the flood risk from the River Soar. However, there are no major developments proposed in Charnwood so the impact of upstream development in this authority is considered negligible. Similary, the impact of development within South Derbyshire on the Flows within the River Trent downstream as it forms a boundary with North West Leicestershire is considered minimal.

**Downstream Authorities**
The remaining local planning authorities that share common boundaries with North West Leicestershire include Erewash, Rushcliffe, Hinckley and Bosworth and North Warwickshire.

North West Leicestershire drains to the River Trent in the north and any potential significant downstream impacts of development within North West Leicestershire will affect Erewash and Rushcliffe directly. In addition, development within the River Mease and River Sence catchments may have potential downstream impacts on Hinckley and Bosworth and North Warwickshire. This said, with appropriate development control and management of surface water discharge from new developments these impacts should be negligible.

Of the Local Planning Authorities with common boundaries with North West Leicestershire, Charnwood, Hinckley and Bosworth have completed their SFRAs. Erewash, Rushcliffe and North Warwickshire are in initial stages of undertaking an SFRA and South Derbyshire are in the process of commissioning external parties to undertake an SFRA on their behalf.

# 4.0 FLOOD RISK IN NORTH WEST LEICESTERSHIRE

## 4.1 Sources of Flooding

### 4.1.1 Fluvial

Overview

The primary source of flood risk in North West Leicestershire is fluvial flooding. The north and east of the District is vulnerable from the River Trent and the River Soar, both independently and, in wider flood events, concurrently. The south and west of the District is at risk of fluvial flooding from the River Mease, a tributary of the Upper Trent and the River Sence, a tributary of the River Soar.

Throughout North West Leicestershire there are several other tributaries of the River Trent and the River Soar which present a flood risk, most notably Gilwiskaw Brook and Grace Dieu Brook. Figure A2 in Appendix A shows the outlines for each of the Flood Zones based on a combination of the Environment Agency Flood Map outlines and flood extents from hydraulic modelling and historical events.

The figure shows the main urban areas at risk of flooding are:

- Castle Donington from the River Trent and Castle Donington Brook
- Hemington from the River Trent and Hemington Brook
- Lockington from the River Trent and Lockington Brook
- Kegworth from the River Soar
- Diseworth from Long Whatton Brook
- Osgathorpe from Westmeadow Brook
- Belton from Westmeadow Brook
- Thringstone from Grace Dieu Brook
- Whitwick from Grace Dieu Brook
- Ashby de la Zouch from Gilwiskaw Brook
- Packington from Gilwiskaw Brook
- Measham from the River Mease

Delineation of Zone 1 Low Probability

Zone 1 Low Probability is defined as those areas of land that area outside of the shaded Zone 2 and Zone 3 flood risk areas (as defined below).

Delineation of Zone 2 Medium Probability

Zone 2 Medium Probability is defined in accordance with the Environment Agency Flood Zone Map, except for the River Trent where it is represented by detailed hydraulic modelling.

Delineation of Zone 3a High Probability

Zone 3a High Probability is defined as those areas of the District that are situated below (or within) the 1% AEP (1 in 100) fluvial flood extent. The detailed hydraulic modelling outputs developed by the Environment Agency, where available (refer to Section 3.4), have been adopted for the delineation of Zone 3a High Probability. It should be noted that quarterly revisions of the Environment Agency Flood Map are carried out so that more detailed information will be incorporated such that the Flood

Zone Map is consistent with the detailed modelled outlines. Where there is no detailed hydraulic modelling, the Environment Agency Flood Map represents Flood Zone 3a.

Delineation of Zone 3b Functional Floodplain

Zone 3b Functional Floodplain comprises *"land where water has to flow or be stored in times of flood"*. and PPS25 defines this as "*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".*

For the purposes of the SFRA, functional floodplain represents land where the flow of water is not prevented by flood defences and is subject to flooding with a 5% AEP. It also includes areas of land which are designed for flood storage, e.g. washlands.

### 4.1.2 Sewers

The sewerage infrastructure of North West Leicestershire is largely based on Victorian sewers and there is a risk of localised flooding associated with the existing drainage and sewer system.

Flooding from sewers can occur when the artificial drainage system is overwhelmed, hydraulically, becomes blocked or suffers structural failure or pump failure. Blockage and structural failure incidents tend to be isolated and unpredictable. Severn Trent Water is responsible for the management of the urban drainage system throughout North West Leicestershire including surface water and foul sewerage. Severn Trent Water has procedures in place to respond to and rectify such incidents, which are also recorded on databases to inform maintenance and improvement plans.

Plate 1 shows an example of flooding from sewers when there were problems with the drainage capacity within Packington during the July 2001 flood event; however flooding from the drains was masked by the flooding of the road later by Gilwiskaw Brook.

***Plate 1 – Drainage problems in Packington during July 2001 (Source: FLOAT)***

A review of areas where the sewer system has been overwhelmed can potentially identify under capacity of the drainage system or where the system does not provide an adequate level of service. Severn Trent Water maintains an extensive database of incidents of hydraulic overload of sewers. This is a strategic level problem and is addressed by Severn Trent Water through their ongoing asset management procedures, supported by a programme of detailed network modelling. Severn Trent Water has the following target levels of protection against sewer flooding of properties:

- Foul and combined systems: 1 in 10 to 1 in 50 years (depending on property type).
- Surface water system: 1 in 10 to 1 in 30 years (depending on property type).

Wherever possible, Severn Trent Water seeks to promote the highest specified standard. However, this is dependent on the cost-benefit analysis of the improvement scheme. It is therefore not appropriate for the SFRA to recommend strategic options for managing sewer flooding where levels of protection to properties are inadequate as this is a fundamental part of Severn Trent Water's existing asset management procedures.

However, Severn Trent Water has made the database of hydraulic overload incidents available and this can form a useful dataset for informing the spatial planning process with regard to flood risk. Figure A2 in Appendix A shows the location of foul and surface water sewer incidents. Within the context of strategic planning, identification of these hotspots will inform North West Leicestershire District Council of areas where increased levels of investment may be required by developers to improve the hydraulic capacity of the existing sewer system. It is essential to ensure that future development does not exacerbate known existing problems and conditions should be placed upon future development to ensure that these capacity issues are rectified before development is permitted to proceed. It is important, however, to consider that all hydraulic improvements to the systems, required due to new development, are subject to approval in line with the strategies and policies of Severn Trent Water.

Severn Trent Water is proposing to invest £3million to tackle sewer flooding in Leicestershire in their current plan (2005-2010). The Water Company is focusing on areas along its 56,000km of sewers that are in need of modernisation. The director of Asset Management and Technology at Severn Trent Water has stated that *"Sewer flooding is unacceptable in this day an age, but we're having to cope with the demands of the 21st century with a system largely designed in the 19th. That has to change and we'll do all we can to make sure our customers get the protection they deserve from the sewer network…….The climate is changing and we know our sewer systems are not up to the demands of the 21st century in places. That can mean some people facing the prospect of sewage flooding their homes, especially during the heavy storms which are becoming more frequent".*[13]

Some properties in Leicestershire have already been outlined for investment in their sewers including four households around Church Lane and Coalville Lane, Ravenstone.

Pipe leakage is a common and widespread problem throughout the UK and can contribute to basement flooding in some areas. Pipe leakage within North West Leicestershire is managed by the Severn Trent Water as a fundamental part of their asset management procedures.

Pipe bursts tend to be isolated and unpredictable incidents. Severn Trent Water has procedures in place to respond to and rectify such incidents.

[13] Severn Trent Website (2007)

### 4.1.3 Groundwater

The majority of North West Leicestershire is underlain by Triassic Mercia mudstone consisting of a series of red clays and marls occasionally interbedded with sandstone. Superficial deposits consist of alluvium deposits in the floodplain interspersed with areas of sand and gravel. Where groundwater exists it flows through strata very slowly and in limited quantities. The Environment Agency has no record of any historical flooding incidences arising from groundwater within North West Leicestershire which is backed up by reference to the Defra Report on groundwater[14]. However, it is difficult to differentiate groundwater flooding with fluvial and surface water flooding during severe events. Groundwater flooding is considered to be relatively minor within North West Leicestershire but can contribute to flooding from other sources.

Parts of North West Leicestershire are susceptible to rising groundwater due to the large-scale closure of the coal mines within the Leicestershire and South Derbyshire coalfield. The closure of a mine and the cessation of water pumping results in the re-saturation of the mine void by water. The residual body of the Coal Board, the Coal Authority is responsible for monitoring rising groundwater and the Environment Agency reviews the results through a formal dialogue with the Authority. Groundwater level monitoring undertaken by the Coal Authority across the coalfield indicates that the minewater is still rising and rebound is incomplete.

The possible impacts of rising groundwater in mining areas was the focus of a research and development report prepared for the Environment Agency (Younger and Adams, 1999[15]) which identified flooding impacts. Younger and Adams report was based on data from 1998 but their work was updated for inclusion within the Groundwater Flooding Scoping Study. The Scoping Study report states that the current status of the South Derbyshire Coalfield is that rebound is underway and localised flooding may be possible as there is no prevention scheme in place. Figure A2 in Appendix A shows an outline of the former coalfield where there are potential issues with rising groundwater.

Detailed site investigations should be undertaken as part of a flood risk assessment for a proposed development site to ascertain any risk of groundwater flooding within the area outlined in Figure A2. The Coal Authority should also be contacted at the planning application stage to identify any monitoring undertaken in the vicinity of the site and to provide groundwater level details.

### 4.1.4 Canal Infrastructure

The Ashby Canal is about 22 miles long from Marston Junction on the Coventry Canal near Bedworth, through largely rural and remote countryside to its present terminus at Snareston. Constructed mainly to carry coal, the canal opened in 1804 and was taken over by the Midland Railway company in 1846. Its railway owners did not invest sufficient money in the canal to maintain it properly and in 1918 a major breach caused by mining subsidence caused the last few miles of the canal near Ashby to be abandoned. Now the mining industry in the area has gone, there are plans to re-open the canal to the National Forest visitor centre at Moira, about one mile short of its original terminus at Spring Cottage. A stretch of the canal near Moira has been restored and re-filled with water with further restoration planned. It is proposed to open Ashby Canal to Moira in the longer term Ashby Canal is owned and maintained by British Waterways. British Waterways have not reported any flooding incidents from the Canal and there is no critical infrastructure which may be subject to failure.

[14] Strategy for Flood and Coastal Erosion Risk Management: Groundwater Flooding Scoping Study (LDS 23) Defra 2004
[15] Younger, P.L. & Adams, R. (1999). Predicting Mine Water Rebound, Research and Development Technical Report W179. Environment Agency

Part of the River Trent and River Soar are maintained as navigable sections by British Waterways. The River Trent is navigable from Shardlow to Trent Lock where it forms part of the boundary of North West Leicestershire.

Northwards from Leicester, the Grand Union Canal utilises the River Soar to provide a through route to the Trent Navigation. The route includes a number of artificial canals, canalised river sections and river navigations. British Waterways state that for this section of the River Soar "*flooding is comparatively common in winter*"[16]. In July 2007 flooding was experienced at several locks along the Soar, including Kegworth (see photos below (Plate 2) and Figure A2 in Appendix A for location of the lock).

Kegworth Lock during normal conditions

Kegworth Lock during July 2007 flood

***Plate 2: Kegworth Lock (Source: British Waterways)***

There are no connections between the Grand Union Canal and the River Soar in the form of overflows so the risk of flooding from the canal is considered to be minor.

### 4.1.5 Reservoirs

There are two reservoirs within North West Leicestershire, Blackbrook Reservoir and Staunton Harold Reservoir (see Figure A2 in Appendix A). Black Brook Reservoir is a large body of water near Whitwick and was constructed in 1796 in order to feed the Charnwood Forest canal, which has long since vanished. The first earth embankment dam failed in 1799 and was subsequently repaired in 1801. The present gravity dam was constructed in 1906. Black Brook is rarely used by its operators, Severn Trent Water, as a water supply source, and as such is maintained at, or close to, full capacity. With the exception of particularly dry periods, the reservoir continuously spills over six equal length weirs into a stilling pool which flows into the Black Brook. The reservoir spans across North West Leicestershire District and Charnwood Borough.

Staunton Harold Reservoir was created in 1964 to provide communities and businesses in Leicester and the East Midlands with drinking water and is currently owned and maintained by Severn Trent Water. The Reservoir spans across North West Leicestershire and South Derbyshire Districts with the majority of it being in South Derbyshire.

Flooding from reservoirs can occur when water retaining structures fail. All large reservoirs are covered by the Reservoirs Act and are subject to regular safety inspections. A very low residual risk of flooding from these reservoirs remains if they were to fail unexpectedly, however this is considered to be a risk that is managed by the Water Companies or the Local Authority.

[16] Waterscape. River Soar (2007)

### 4.1.6 Surface Water

Surface water flooding occurs when excess water runs off across the surface of the land. Surface water flooding has the potential to contribute significant flood risk in urban areas due to the rapid run off rates associated with urban land use.

Surface water flooding, either on its own or as a contributing factor in other types of flooding is considered to be relatively frequent. The scale of the disruption or damage caused is less certain, and there are few records of significant losses resulting from surface water flooding.

Surface water flooding is largely caused by rapid run-off and insufficient local drainage capacity, and tends to be a problem within older urban areas where slopes may be gentle, but run-off is rapid due to the impervious surfaces, e.g. Coalville and Ashby-de-la-Zouch. In addition, in some areas in the catchment the drainage network may not have enough storage capacity and, where discharge is directly to a watercourse, locally high water levels may prevent drainage taking place. Surface water flooding can also result from run-off associated with various agricultural practices. Certain arable farming practices in particular are likely to increase this risk of surface water flooding and excessive loss of top soil; however this is considered to be a minor problem within the District.

No specific problem areas have been identified as suffering from severe interruption and damage through surface water flooding within North West Leicestershire, and as such this source of flooding is not considered a high priority in terms of the relative scale of potential flood damages compared to other types of flooding in the District.

### 4.1.7 Failure or Blockage of Critical Assets

Flooding can result from the failure or blockage of critical assets, for example culverts or bridges. When trash screens become significantly reduced due to the build up of debris, or where blockages occur at the inlet to culverts, there is potential for localised flooding to result. The floodwater backs up and can flood nearby land or low-lying areas as it finds an alternative route around the culvert or structure.

For example, the City of Dan culvert along Grace Dieu Brook through Whitwick is susceptible to blockage. Consequently, water quickly accumulates upstream of the culvert which has led to overtopping of the structure and flooding along Castle Street.

## 4.2 Flood Defences

Where there are flood defences with a standard of protection of at least 100 years, the area benefiting from these defences has been assessed. Figure A2 shows the areas benefiting from flood defences for a 1% AEP event. The main areas benefiting from flood defences along the River Trent are Castle Donington with approximately 250 properties protected; Hemington with approximately 150 properties protected; and Lockington with approximately 50 properties protected.

In addition, there are defences along the Soar, which protect a small number (<20) of properties within Kegworth.

Within North West Leicestershire there is also a considerable length of flood defences which have less than a 100 year design standard. Whilst these defences offer protection to properties for flood events up to their design standard, for the 1% AEP event the defences offer little protection and are overtopped.

## 4.3 Flood Risk Sensitivity

A sensitivity analysis has been undertaken of the risk of flooding in North West Leicestershire to potential changes caused by climate change and the variability associated with urban development and land management practices. In addition, the impact of overtopping and breaching of flood defences on the flood risk has been considered.

### 4.3.1 Flood Sensitivity to Climate Change

The Trent CFMP identifies that climate change is expected to have a major influence on future flood risk. The expectations are that winter floods will happen more often and in urban areas flooding from thunderstorms will be more regular and more severe.

Recent guidance from Defra[17] on assessing climate change sensitivity recommends assuming a 10% increase in fluvial flow up to 2025 and then an increase of 20% thereafter.

Hydraulic modelling of the Trent and Grace Dieu Brook has considered the potential impact of climate change over the next 100 years, assuming a 20% increase in the 1% (100 year) flow and outlines are available from previous studies undertaken for the Environment Agency.

For Gilwiskaw Brook, Hooborough Brook, River Mease and parts of the River Soar a 20 increase in the 1% (100 year) flow has not been modelled. For these watercourses the Flood Zone 2 outline (0.1% AEP) has been used to represent climate change.

The outlines representing climate change in Figure A2 in Appendix A indicate that there would be a small increase in the number of properties at risk of flooding compared with the 1% AEP outline. The impact of Climate Change for each of the main watercourses in North West Leicestershire are discussed further below.

River Trent

There would be no difference in the flood outline for the River Trent and no increase in the number of properties at risk; however the Fluvial Trent Strategy report suggests an average increase in water levels of 350mm as a result of climate change.

River Soar

There is no significant difference in the flood outlines for the River Soar except for at Kegworth where there are up to 100 further properties and a sewage treatment works at risk with climate change. However, this flood outline is based on the 0.1% AEP so the actual risk from climate change will be lower than that shown.

[17] Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts. Defra. October 2006

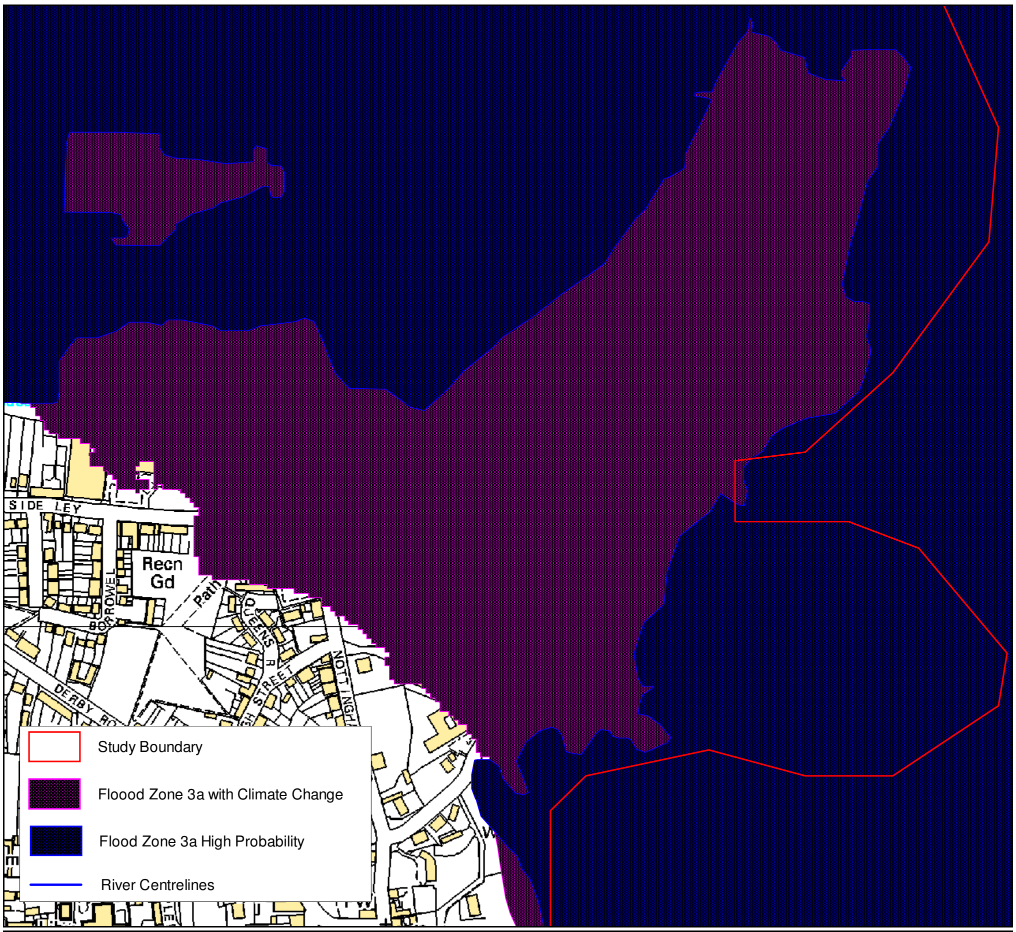


***Figure 1 - Climate Change Impact on the River Soar*** (© Crown Copyright Licence No. 100026380 (2007))

<u>Grace Dieu Brook</u>

There would be approximately 15 properties at risk from Grace Dieu Brook within Whitwick particularly around Cademan Street and Vicarage Street due to flow out of bank at the Leicester Road culvert. Flood depths within this part of Whitwick are predicted to have a maximum increase of 280 mm as a result of climate change.

Along the rest of Grace Dieu Brook there are similar increases in flood depths and flood extents; however there are no further properties or roads at risk from climate change.

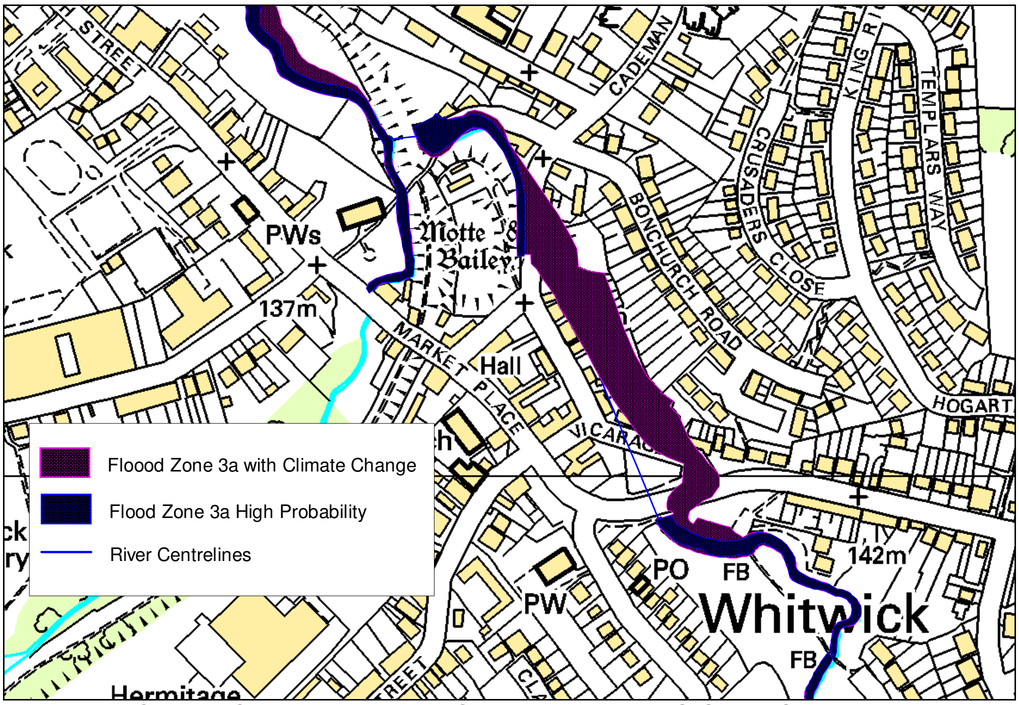


***Figure 2 – Climate Change Impact on Grace Dieu Brook*** (© Crown Copyright Licence No. 100026380 (2007))

<u>Gilwiskaw Brook</u>

The effect of climate change on Gilwiskaw Brook would be to increase the extent of flooding in the Ashby de la Zouch town centre and the southern parts of the town around Western Park. There are up to a further 20 properties at risk from climate change; however the depth of flooding is estimated as less than 100mm.

The extent of flooding would also increase through the village of Packington with up to 5 properties affected by climate change; however the depth of flooding will be small (less than 100mm).

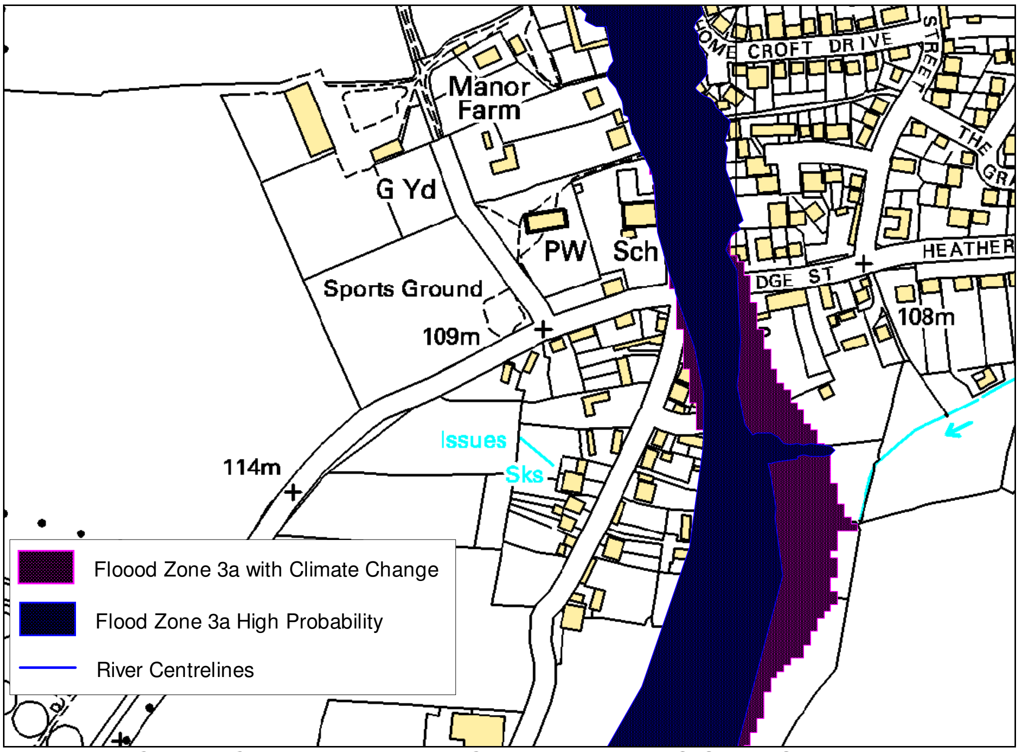


***Figure 3 – Climate Change Impacts on Gilwiskaw Brook*** (© Crown Copyright Licence No. 100026380 (2007))

<u>River Mease</u>

Climate change would also increase flood risk in Measham with an additional property at risk on Westminster Industrial Estate. There is no increase in residential property at risk but Birds Hill Road and a small part of Wordsworth Way will be at risk of flooding from climate change.

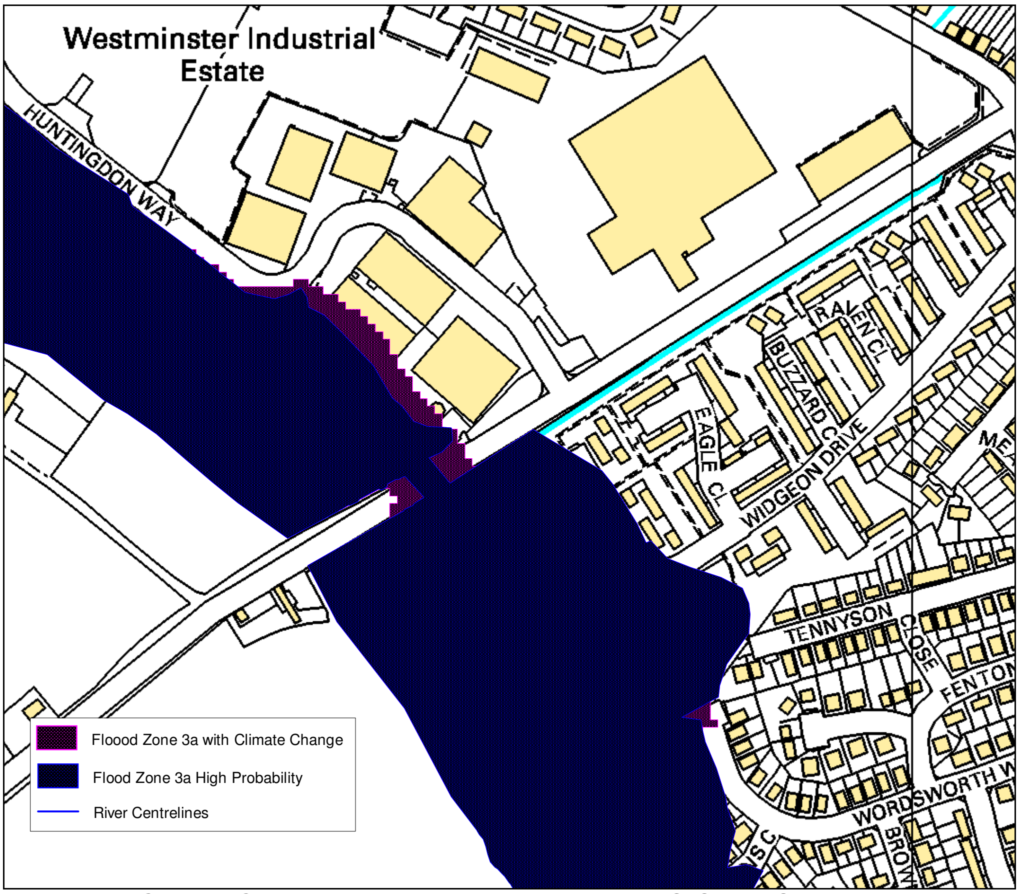


***Figure 4 – Climate Change Impact on the River Mease*** (© Crown Copyright Licence No. 100026380 (2007))

The anticipated changes in climate change have the potential to not only increase the risk of fluvial flooding but also, by increasing the frequency and intensity of localised storms, increase the occurrence of flash flooding in small catchments. This may exacerbate localised drainage problems and so any site-based detailed Flood Risk Assessment and the Drainage Impact Assessment prepared by a developer at the planning application stage should take due consideration of climate change.

Impacts of climate change upon specific potential development sites are discussed later within this document.

### 4.3.2 Flood Sensitivity to Increased Urban Development

The effects of flooding due to increases in urbanisation have been tested on a number of different catchments within the Trent CFMP. The findings show that storm run-off from impervious surfaces, if controlled and routed rapidly by artificial drainage networks, can increase flood peaks in watercourses downstream of new urbanised areas. There is also an increased risk of localised “flash flooding” in intense rainstorms. Urban growth will, therefore, increase surface water run-off rates and volumes with the potential for increasing flood risk unless new development is properly controlled.

Through new developments there is an opportunity to reduce surface water flood risk for the following reasons:

- Some of the new development is likely to be located on “brownfield” sites. These sites may already have connections to the drainage network. Therefore, unless the land use significantly increases the impermeable surface area, new development is unlikely to increase surface water flood risk. An exception to this would be where low density residential areas of large houses, with extensive gardens, are replaced by high density developments of flats or smaller houses. However, with the use of sustainable urban drainage schemes (SUDs) any potential adverse effects can be avoided. The Environment Agency encourages a 20% reduction in surface water flows emanating from brownfield sites to reduce river flows by 20% to account for climate change.

- For any "greenfield" allocations, surface water discharges from new developments into watercourses would be controlled by the Environment Agency to ensure existing greenfield runoff rates are maintained post development.

Developers have to approach Severn Trent Water to determine if they have the capacity to allow a new development to connect to the existing drainage system. Severn Trent Water will either allow connection if they have capacity or inform the developer that an increase in capacity is required and that the developer would have to cover the cost before connection is permitted. However, connecting new developments into the Severn Trent Water drainage system is not sustainable as surface water sewers discharge into the watercourses. Effort should be made to attenuate surface water runoff on the site so it does not put pressure on the existing drainage system or increase runoff into watercourses via the sewer network.

Clever design, situation and location of future development can, therefore, all contribute to reducing the risk of flooding, including:

- Steering developments outside of the floodplain;
- Application of property and location specific flood protection measures;
- Improving property resilience to flood damage;
- Identifying river corridors and the natural flood plain to provide potential riverside storage and urban river corridors in built up areas;
- Application of sustainable urban drainage techniques for new developments.

### 4.3.3 Flood Sensitivity to Land Management Practices

The volumes and rate of runoff from land into watercourses and rivers can be greatly affected by agricultural practices, such as the removal of hedgerows and woodland areas, reshaping landform and the provision of positive land drainage. Such practices can result in an increase in the flood risk from these watercourses to areas downstream.

The influences for change in land use and land management have been explored in the Trent CFMP. The agricultural land within North West Leicestershire is mainly classified as Grade 3 and is characterised by mixed land use. There are small areas of Grade 2 land along the River Trent and there is intensive agricultural use of the floodplain. In many places the floodplain is no longer naturally linked to the river due to engineered flood defences and river channels which protect this agricultural land from flooding.

There is a strong link between land use and land management practices and runoff generation at a plot or individual field scale. However, research into the potential impact of rural land use and land management practice on flood generation at a catchment scale is still underway. Ongoing research funded by Defra[18] and the Environment Agency is evaluating the impacts of rural land use and land management on run-off and flood generation. So far, it has concluded that impacts

[18] Defra / Environment Agency R&D Project Record FD2114/TR Review of impacts of rural land use and management on flood generation. (2004)

are evident at the local scale (individual fields and very small stream catchments). Further research is required to identify and understand impacts for larger catchments. It also appears that land management effects are most notable for small to medium flood events. In extreme floods the overall volume of rainfall is the controlling factor for flood magnitude.

It is very difficult to predict future changes in agricultural land use and management within North West Leicestershire; however as arable farming is already intensive in places, it is thought that any changes in land management practices are not going to significantly affect runoff and, therefore, flood risk.

### 4.3.4 Flood Sensitivity to Breach and Overtopping of Flood Defences

**Overview**

Areas behind flood defences are at risk due to the potential overtopping or breach of flood defences resulting in the rapid onset of fast-flowing and deep water flooding with little or no warning. Local Planning Authorities and developers need to consider these residual risk issues relating to a development.

The level of residual risk behind flood defences is dependent on the distance from and the relative elevation of the land in relation to the water source. The Figure below illustrates the various risk zones behind a river flood defence.

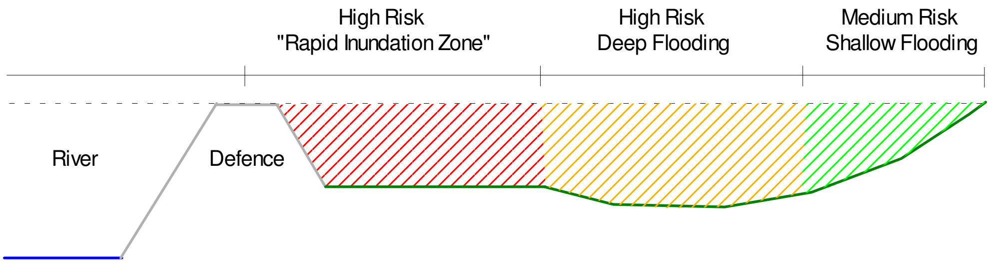


***Figure 5 – Risk Zone behind Flood Defences***

A Rapid Inundation Zone is an area which is at risk of rapid flooding should a flood defence structure be breached or overtopped. The zone at highest risk from rapid inundation is the area located close behind a flood defence.

**Breach of Defences**

The breaching of a flood defence is a worst-case scenario for a flood event. During a breach event, a section of the flood defence fails, allowing large quantities of flood water to pass through the opening in the defence (see Plate 3). The likelihood and scale of a breach is dependent on many factors, in particular, the material composition and condition of the defence.

***Plate 3 - Breaching of a flood defence embankment (Source: Atkins)***

Flood hazard describes the physical risk that floodwater presents to people (and to vehicles and property) It is a function of water depth (D), velocity (v) and a debris factor (DF). The flood hazard classification is summarised in Table 3.

***Table 3 – Flood Hazard Classification (risks to people)***

| Flood Hazard Rating (D x (v + 0.5) + DF | Degree of Flood Hazard | Description |
|---|---|---|
| <0.75 | Low | Caution – flood zone with shallow flowing water or deep standing water |
| 0.75-1.25 | Moderate | Dangerous for Some (i.e. children) – Danger: flood zone with deep or fast flowing water |
| 1.25-2.5 | Significant | Dangerous for most people – Danger: flood zone with deep fast flowing water |
| >2.5 | Extreme | Dangerous for all – Extreme danger: flood zone with very deep fast flowing water |

Defra guidance FD2320[19] illustrates schematically (replicated below) how danger to people or flood hazard varies in relation to the distance from a defence (or breach location).

[19] Flood Risk Assessment Guidance for New Development: Phase 2 R&D Technical Report FD2320/TR2; Defra, October 2005

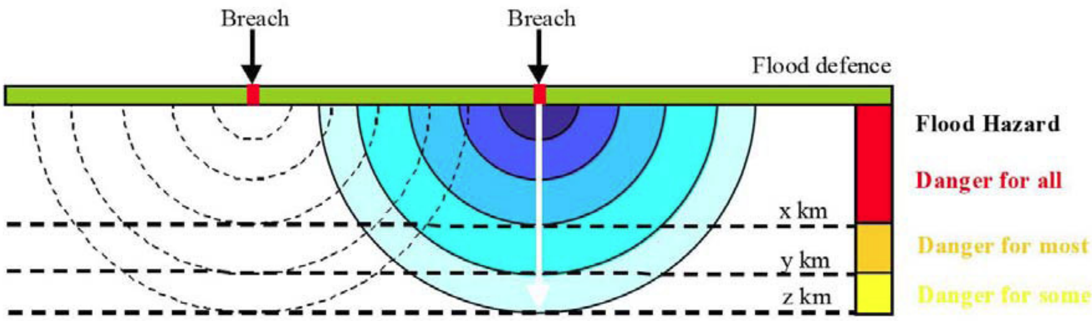


***Figure 6 – Flood Hazard from a Breach of Flood Defences***

Breach analysis has been undertaken of the flood defences along the River Trent which protect properties in Castle Donington, Hemington and Lockington (see Figure 7).

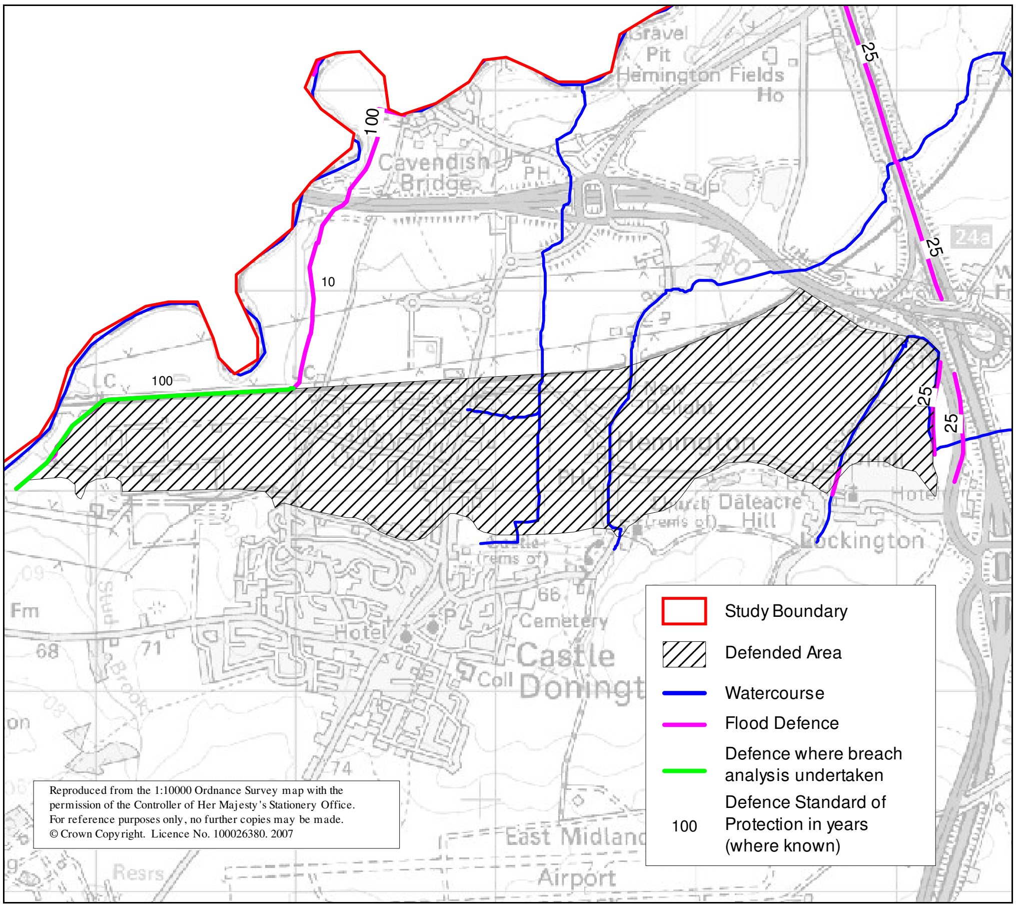


***Figure 7 - Reach of Defences where Breach Analysis Undertaken in Castle Donington***

Atkins has developed in-house look up tables for breach analysis to determine the depths, velocities and hazard ratings associated with a breach. Table 4 summarises the range of values expected for a breach of the flood defences on the River Trent. The assumptions undertaken for the breach analysis is that the breach of the defence is 50m wide and the depth of water behind the flood defence prior to the breach is 2-3m for a 1% AEP event. A 1% AEP event has been used for the breach analysis as this is the current standard of protection offered by the flood defences near Castle Donington.

***Table 4 – Breach analysis of flood defences on the River Trent near Castle Donington***

| Distance from breach (m) | Depth of flooding (m) | Velocity of Flood Water (m/s) | Flood Hazard Rating |
|---|---|---|---|
| 100 | 0.6 - 0.8 | 1.1 - 1.8 | 1.6 - 2.8 |
| 200 | 0.4 - 0.6 | 0.6 - 0.8 | 0.8 - 1.5 |
| 500 | 0.2 - 0.4 | 0.3 - 0.4 | 0.4 - 0.7 |
| 1000 | 0.1 - 0.2 | 0.1 - 0.2 | 0.2 - 0.3 |

Where Level of Risk _ is Significant, _ is Moderate and _ is Low

Breach analysis has also been undertaken of the flood defences along the River Soar which protect Bridge Farm and properties in Kegworth (see Figure 8).

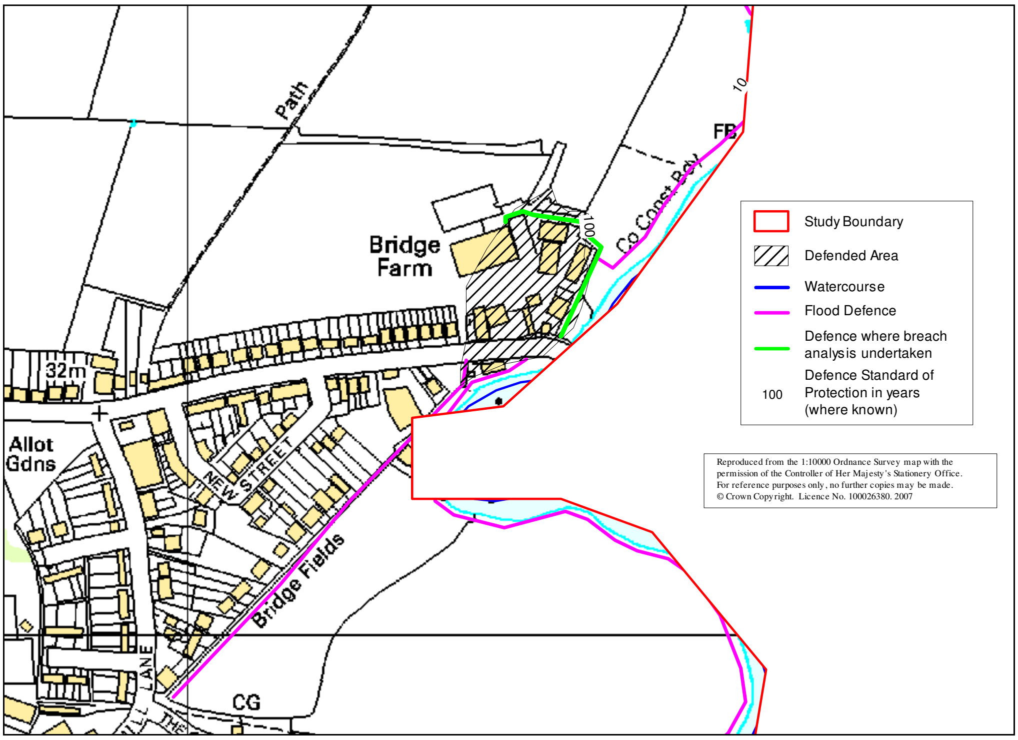


***Figure 8 - Reach of Defences where Breach Analysis Undertaken in Kegworth***

Table 5 summarises the range of values expected for a breach of the flood defences on the River Trent. The assumptions undertaken for the breach analysis is that the breach of the defence is 50m wide and the depth of water behind the flood defence prior to the breach is 1-2m for a 1% AEP event. A 1% AEP event has been used for the breach analysis as this is the current standard of protection offered by the flood defences near Kegworth.

***Table 5 – Breach analysis of flood defences on the River Soar near Kegworth***

| Distance from breach (m) | Depth of flooding (m) | Velocity of Flood Water (m/s) | Flood Hazard Rating |
|---|---|---|---|
| 100 | 0.3 - 0.6 | 0.5 - 1.1 | 0.7 – 1.6 |
| 200 | 0.2 - 0.4 | 0.3 - 0.6 | 0.4 – 0.8 |
| 500 | 0.1 - 0.2 | 0.1 - 0.3 | 0.2 - 0.4 |
| 1000 | 0.0 - 0.1 | 0.0 - 0.1 | 0.1 - 0.2 |

Where Level of Risk _ is Significant, _ is Moderate and _ is Low

**Overtopping of Defences**

The majority of the flood defences within North West Leicestershire have a standard of protection of less than 2% AEP (50 year) with some only having a standard of protection of 10% AEP (10 year). Where the existing defences have a standard of protection less than 1% AEP they will be easily overtopped and even submerged during a 1% AEP flood event (see Figure 9). Out of bank flow will occur in a manner almost as if no defences existed. In these circumstances flood depths, velocities and extent can be expected to be similar to the undefended situation.

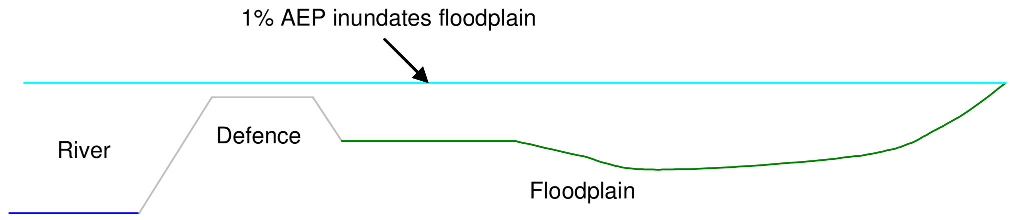


***Figure 9 – Overtopping of Defences with Standard of Protection less than 1%AEP***

The flood defences along the River Trent and the River Soar which currently offer a standard of protection of 1% AEP event would be overtopped by more severe events, e.g. 0.1% AEP but also by increased water levels as a result of climate change. The impact of Climate Change was assessed as part of the Fluvial Trent Strategy. For the location of the flood defences near to Castle Donington (with asset name d/s Trent / A6 crossing) an increase in water levels of 0.5m is predicted. The result of overtopping of the flood defences is likely to result in a moderate level of risk in close proximity to the defences (100-200m) due to depths of water of >0.5m. However, at a greater distance (>500m) from the defences, the depth of flooding will be less as will the level of risk.

# 5.0 PPS 25 AND THE SEQUENTIAL TEST

## 5.1 Background

The Government expects Local Planning Authorities (LPAs) to apply a risk-based approach to the preparation of development plans and their decisions on development control. The introduction of Planning and Policy Statement: Development and Flood Risk (PPS 25) in 2006 has encouraged LPAs to steer development away from areas affected by flood risk and recommends the application of a 'Sequential Test' that splits a local planning district into zones of high, medium or low risk. PPS 25 is the key guidance for planners managing flood risk as it clearly defines the appropriateness of the development type for each of the defined flood risk zones.

As stated above, the sequential test splits the planning district into three distinct flood risk zones, furthermore, the high flood risk zone is split further into areas of Functional Floodplain and High Probability Floodplain (see Figure 10 below).

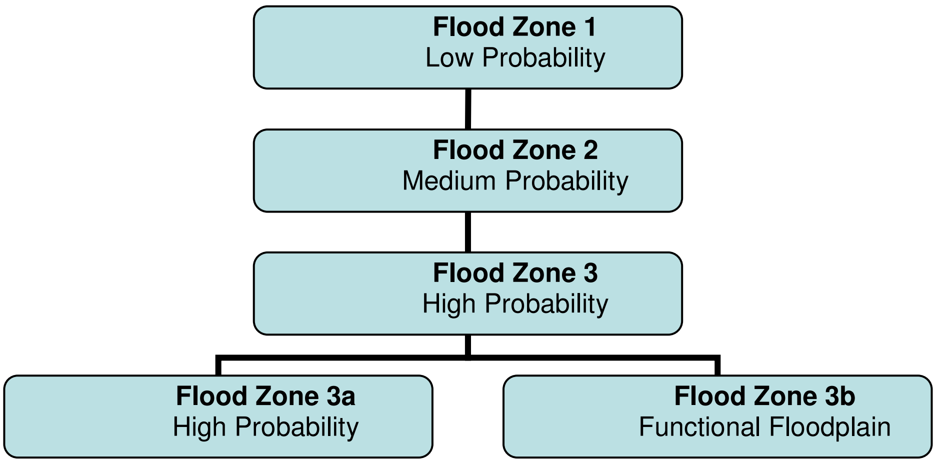


***Figure 10 – Flood Zones***

## 5.2 Sequential Test

Historically settlements have evolved along river corridors where the river has provided a source of water, food, transport and energy. The result of this is that many of the urban centres of England are at risk of flooding due to their close proximity to rivers.

Planning needs to be at the forefront of managing flood risk in a sustainable manner by steering development away from areas that are susceptible to flooding. PPS25 advocates a sequential approach that will guide the planning decision making process (i.e. the allocation of sites). The aim of the Sequential Test is to:

*"steer new development to areas at the lowest probability of flooding (Flood Zone 1). Where there are no reasonably available sites in Flood Zone 1, decision-makers identifying broad locations for development and infrastructure, allocating land in spatial plans or determining applications for development at any particular location should take into account the flood risk vulnerability of land uses and consider reasonably available sites in Flood Zone 2, applying the Exception Test if required. Only where there are no reasonably available sites in Flood Zone 1 or 2 should*

*decision-makers consider the suitability of sites in Flood Zone 3, taking into account the flood risk vulnerability of land uses and applying the Exception Test if required".*

*"Within each flood zone, new development should be directed first to sites at the lowest probability of flooding and the flood vulnerability of the intended use matched to the flood risk of the site, e.g. higher vulnerability uses located on parts of the site at lowest probability of flooding".*

A Sequential Test approach has been undertaken using the potential development sites as identified within the North West Leicestershire Local Plan, potential housing sites, the Urban Capacity Study and Leicestershire Minerals and Waste Development Frameworks. These documents provide information on the potential land uses and the boundary extents of these potential development sites.

The flood risk for each of the proposed development sites has been assessed to identify whether the proposed land uses are appropriate for the level of flood risk at each site. Furthermore, where required, sites which require the Exception Test have been identified.

## 5.3 Assessing Flood Risk Using the Sequential Test

### 5.3.1 Methodology

Figure 11 sets out the methodology adopted to undertake the Sequential Test in the form of a flow diagram. This diagram identifies the steps undertaken to identify the flood zones that each of the proposed development sites reside, these steps are outlined below;

1. Obtain the latest editions of the Environment Agency Flood Map and overlay within a Geographic Information System (GIS) for review.

2. Based upon catchment flood knowledge, historical flooding and hydraulic modelling update Flood Zones 2 and 3 if appropriate.

3. Identify Functional Floodplain using hydraulic model data where available. Assign this area as Flood Zone 3b.

4. Review North West Leicestershire Local Plan, Urban Capacity Study, Leicestershire Minerals Development Framework Site Allocations (Preferred Options) 2021 and Leicestershire and Leicester Waste Development Framework Site Allocations (Preferred Options) 2021 and identify all allocation and potential sites within the District. In conjunction with North West Leicestershire District Council Planning Department review these sites and agree on potential development sites for the SFRA and digitise within GIS.

5. Incorporate the potential development sites and the Flood Zone maps within GIS environment.

6. Determine which Flood Zone each of the proposed development sites are located and tabulate the results.

7. Identify a hierarchy of preferred sites based on flood risk.

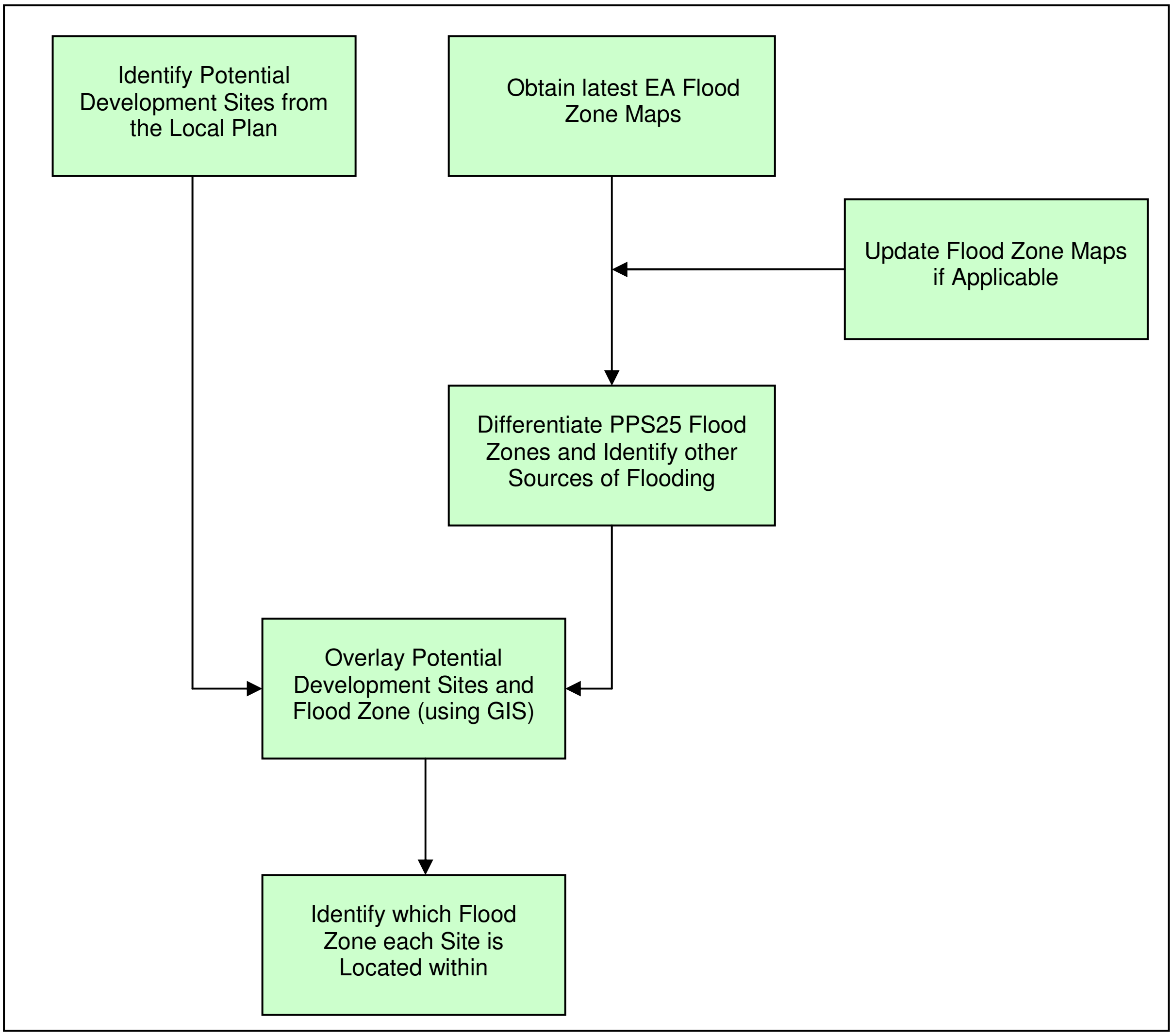


***Figure 11 - Flow diagram of sequential test methodology***

### 5.3.2 Summary of Results

A summary of the flood risk for the potential development sites is provided within Table 6below. The complete results of the analysis are contained within Appendix B. Figure A3 in Appendix A contains a map showing the location of all 58 potential development sites and the Flood Zone within which they are located.

***Table 6 – Summary of the Potential Development Sites and Flood Zones***

| Total Number of Potential development sites | Flood Zone 1 Low Probability | Flood Zone 2 Medium Probability | Flood Zone 3a High Probability | Flood Zone 3b Functional Floodplain |
|---|---|---|---|---|
| 58 | 42 | 0 | 6 | 10 |

Many of the potential development sites are situated within more than one Flood Zone, where this is the case, the site is shown in the table as being in the zone with the higher probability of flooding.

In total, there are 58 potential development sites within the District Boundary. 42 of these sites are identified to fall within Flood Zone 1 'Low Probability' and therefore all uses of land/development types would be appropriate. However for developments on sites of 1 Ha or larger a site-specific Flood Risk Assessment is required.

No sites are identified to be within Flood Zone 2 'Medium Probability'.

The remaining 16 sites are all identified to fall within Flood Zone 3, of which 6 are within Flood Zone 3a 'High Probability' and the remaining 10 within Flood Zone 3b 'Functional Floodplain'. In Zone 3a Less Vulnerable and Water Compatible uses are deemed appropriate. More Vulnerable and Essential Infrastructure require the Exception Test to be passed and Highly Vulnerable development should not be permitted. In Zone 3b only Water Compatible uses are deemed appropriate. Essential Infrastructure requires the Exception Test to be passed. All other uses should not be permitted.

### 5.3.3 Site Specific Results

North West Leicestershire District Council have identified the proposed land uses for each of the potential development sites assessed within the SFRA, the application of the Sequential Test to each of these sites and the intended land uses has resulted in 3 groupings:

1. Sites where proposed land use is appropriate
2. Sites which require application of the Exception Test
3. Sites where the intended land use is not appropriate

The first group, sites where land use is appropriate, contains 46 separate sites across North West Leicestershire and includes a mix of sites within Flood Zones 1, 3a and 3b. Table 7 below identifies these sites with no restrictions on their proposed development purposes.

The majority of the proposed development sites are situated in Flood Zone 1, which is appropriate for all land uses; these include housing, classified as More Vulnerable (36 no. sites), and employment (5 no. sites) and waste (5 no. sites) both of which are classified as Less Vulnerable.

There are two proposed employment sites (J3a and J3f) within Flood Zone 3a which is appropriate for Less Vulnerable developments such as offices, shops, restaurants, etc. Site J3a Swainspark has a significant flooding history as a result of inadequate capacity of the site culverts. Although the development may be considered appropriate there is a requirement for flood risk to be adequately mitigated.

The mineral site at Lockington (MS1) is situated within Flood Zone 3b Functional Floodplain. The proposed use for this site is sand and gravel extraction which is regarded as water compatible development in Table D2 of PPS25.

***Table 7 – Summary of the Potential Development Sites where Development is Appropriate***

| Site | Potential Development Site Name | Proposed Use | Flood Zone |
|---|---|---|---|
| J3a | Swainspark Industrial Estate, Albert Village | Employment | FZ3a |
| J3b | Smisby Road, Ashby de la Zouch | Employment | FZ1 |
| J3d | South of Coalville Brickworks | Class B1 | FZ1 |
| J3f | South of Trent Lane, Castle Donington | Employment | FZ3a |
| J3h | Former Walton Wat Drift Mine, Oakthorpe | Employment | FZ1 |
| H4d | Broom Leys Road, Coalville | Housing | FZ1 |
| H4e | Wentworth Road, Coalville | Housing | FZ1 |
| H4h | Brooks Lane, Whitwick | Housing | FZ1 |
| H4i | North of Park Lane, Castle Donington | Housing | FZ1 |
| H4o | Main Street, Oakthorpe | Housing | FZ1 |
| A709 | 2-2a Derby Road, Ashby | Housing | FZ1 |
| C1 | Land between No.s 125-149 Grange Road | Housing | FZ1 |
| C3 | Land at St. Marys avenue | Housing | FZ1 |
| C9 | Council Depot, Highfield Street, Coalville | Housing | FZ1 |
| C11 | Land south of Forest Road | Housing | FZ1 |
| C12 | Land adjacent to Minnesota's | Housing | FZ1 |
| C17 | Church Lane, Whitwick | Housing | FZ1 |
| C20 | Pumping Station, Hall Lane | Housing | FZ1 |
| C23 | Land off Ashby Road | Housing | FZ1 |
| C27 | Part of Snibston Discovery Park | Housing | FZ1 |
| C700 | Enterprise House, Ashby Road, Coalville | Housing | FZ1 |
| C705 | Land at Ashby Road, Coalville | Housing | FZ1 |
| C707 | Land adjacent to Discovery Park, Ashby Road, Coalville | Housing | FZ1 |
| C801 | Land at Cropston Drive, Coalville | Housing | FZ1 |
| CD7 | Land East of High Street | Housing | FZ1 |
| CD702 | Donington Mill, Station Road, Castle Donington | Housing | FZ1 |
| IB2 | Land off High Street, Ibstock | Housing | FZ1 |
| IB3 | Poplar Farm, High Street | Housing | FZ1 |
| IB6 | Land between 112 and 128 Melbourne Road | Housing | FZ1 |
| K2 | Land east of Packington Hill | Housing | FZ1 |
| K5 | Computer Centre, Derby Road, Kegworth | Housing | FZ1 |
| K6 | Land to the rear of 'the computer centre', Kegworth | Housing | FZ1 |
| K703 | Brookes Machine Tools Ltd, 2 Derby Road, Kegworth | Housing | FZ1 |
| K705 | Slack and Parr Ltd, Long Lane Kegworth | Housing | FZ1 |
| M1 | Land east of High Street, Measham | Housing | FZ1 |
| M2 | Former Youth Club and Land West of High Street, Measham | Housing | FZ1 |
| M3 | Land at rear of 34-54 Chapel Street, Measham | Housing | FZ1 |
| M6 | Land off New Street, Measham | Housing | FZ1 |
| M8 | Land off New Street, Measham | Housing | FZ1 |
| M702 | Land North East of Atherstone Road, Measham | Housing | FZ1 |
| M703 | 3a New Street Measham | Housing | FZ1 |
| WS1 | Swainspark | Materials Recovery/Aggregates Recycling/Composting | FZ1 |
| WS2 | Donnington Island | Mineral Stocking | FZ1 |
| WS6 | Little Wigston | Aggregate Recycling | FZ1 |

***Table 7 – Summary of the Potential Development Sites where Development is Appropriate (cont'd)***

| Site | Potential Development Site Name | Proposed Use | Flood Zone |
|---|---|---|---|
| MS1 | Lockington (mineral) | Sand and gravel extraction | FZ3b |
| MS2 | Ibstock | Non-inert landfill | FZ1 |

The second group of sites; those which require the Exception Test to be undertaken, include a total of four sites each of which are located within Flood Zone 3a. The extent to which these sites are affected by Flood Zone 3a varies considerably and is discussed within the site specific assessments below. Table 8 provides details of these sites. In terms of the Sequential Test, these sites are only preferable once all other housing in lower flood risk zones have been taken up.

***Table 8 – Summary of the Potential Development Sites where the Exception Test is required***

| Site | Potential development site Name | Proposed Use | Flood Zone |
|---|---|---|---|
| H4a | Leicester Road, Ashby de la Zouch | Housing | FZ3a |
| H4j | Station Road, Castle Donington | Housing | FZ3a |
| H4k | High Street, Ibstock | Housing | FZ3a |
| K705 | Slack and Parr Ltd, Long Lane Kegworth | Housing | FZ3a |

<u>H4a Leicester Road, Ashby de la Zouch</u>

The proposed land use for this site is housing which is a More Vulnerable use. It is identified that Flood Zone 3a covers less than 1% of the site, and therefore, through careful planning and arrangement of the site the More Vulnerable uses can be located outside of Flood Zone 3a such that the need for an Exception Test can be mitigated. This issue should be addressed within the site specific FRA.

<u>H4j Station Road, Castle Donington</u>

The proposed land use for this site is of housing which is a More Vulnerable use. It is identified that Flood Zone 3a covers nearly 60% of the site. It is necessary to assess whether the intended housing use on this site could be swapped with another site which has current proposals of Less Vulnerable land usage. If this is not feasible, an Exception Test will be required. Through careful planning and arrangement of the site the More Vulnerable uses could be located outside of Flood Zone 3a; however this may affect the viability of the site. This issue should be addressed within the site specific FRA.

<u>H4k High Street, Ibstock</u>

The proposed land use for this site is housing which is a More Vulnerable use. It is identified that Flood Zone 3a covers only 2% of the site, and therefore, through careful planning and arrangement of the site the More Vulnerable uses can be located outside of Flood Zone 3a such that the need for an Exception Test can be mitigated. This issue should be addressed within the site specific FRA.

<u>K705 Slack and Parr Ltd, Long Lane Kegworth</u>

The proposed land use for this site is of housing which is a More Vulnerable use. It is identified that Flood Zone 3a covers nearly 46% of the site. It is necessary to assess whether the intended housing use on this site could be swapped with another site which has current proposals of Less Vulnerable land usage. If this is not feasible, an Exception Test will be required. Through careful planning and arrangement of the site the More Vulnerable uses could be located outside of Flood Zone 3a; however this may affect the viability of the site. This issue should be addressed within the site specific FRA.

The final group includes nine sites, for which, under PPS25 the proposed land uses are deemed inappropriate. All nine sites are located, to some degree, within Flood Zone 3b and are therefore subject to the highest level of constraint on the type of development as imposed by PPS25. However, through the application of a more detailed site specific FRA in conjunction with careful planning of the site it may be possible to reduce the level of constraints imposed. Table 9 provides details of these sites.

***Table 9 – Summary of the Potential Development Sites where the Exception Test is required***

| Site | Potential Development Site Name | Proposed Use | Flood Zone |
|---|---|---|---|
| J3c | Extension to Hilltop Industrial Estate, Bardon | | FZ3b |
| J3g | Extension to Westminster Estate, Measham | | FZ3b |
| J13 | Castle Donington Power Station | Limited to Class B8 | FZ3b |
| H4b | East of Leicester Road, Ashby de la Zouch | Housing | FZ3b |
| H4g | Grange Road, Hugglescote | Railway Station, Local Shopping Centre, primary school, 450 dwellings | FZ3b |
| H4l | South of High Street, Ibstock | Housing | FZ3b |
| WS3 | Hemington Quarry | Continuation of aggregate recycling facility | FZ3b |
| WS4 | Lockington Quarry A | Continuation of aggregate recycling facilities | FZ3b |
| WS5 | Lockington Quarry B | Inert Landfill | FZ3b |

<u>J3c Extension to Hilltop Industrial Estate, Bardon</u>

The Hilltop Industrial Estate in Bardon is situated on the left bank of the River Sence. The extension to the industrial estate is partially within Flood Zone 3b (<20%) with the majority of the site (68%) within Flood Zone 1 (remainder of the site is within Flood Zone 2 and 3a). The proposed land uses for this site are unknown but they are likely to be Less Vulnerable development uses, for example general industry or storage and distribution.

As Flood Zone 3b does not extend across the whole of this site, through careful planning the development may be directed into Flood Zone 1. This issue should be addressed within the site specific FRA.

J3g Extension to Westminster Estate, Measham

The Westminster Estate in Measham is situated on the right bank of the River Mease. The extension to the estate is partially within Flood Zone 3b (16%) with the majority of the site (60%) within Flood Zone 1. The proposed land uses for this site are unknown but they are likely to be Less Vulnerable development uses.

As Flood Zone 3b does not extend across the whole of this site, through careful planning the development may be directed into Flood Zone 1. This issue should be addressed within the site specific FRA.

J13 Castle Donington Power Station

Castle Donington Power Station is situated on the right bank of the River Trent. The proposed land use for this site is for storage or distribution centre which is a Less Vulnerable development. The site is mainly situated within Flood Zone 3a, the breakdown of each flood zone as a percentage of the site area is as follows:

- Flood Zone 1 – 30%
- Flood Zone 2 – 0%
- Flood Zone 3a – 67%
- Flood Zone 3b – 3%

Flood Zone 3b is only a small proportion of the site so through careful planning the development may be directed into Flood Zone 3a and Flood Zone 1. The intended land use is acceptable within Flood Zone 3a.

H4b East of Leicester Road, Ashby de la Zouch

A tributary of Gilwiskaw Brook which runs along the north side of the A42 trunk road flows through the southern portion of the proposed development site, east of Leicester Road, in Ashby de la Zouch. However, the majority (93%) of the development site is situated within Flood Zone 1.

As Flood Zone 3b (similarly Flood Zone 3a and Flood Zone 2) does not extend across the whole of this site, through careful planning the More Vulnerable land use of housing may be directed into Flood Zone 1.

H4g Grange Road, Hugglescote

A tributary of the River Sence flows through this large (89 Ha) development site off Grange Road in Hugglescote. However, the majority (99%) of the development site is situated within Flood Zone 1.

As Flood Zone 3b (similarly Flood Zone 3a and Flood Zone 2) does not extend across the whole of this site, through careful planning the More Vulnerable land use of housing may be directed into Flood Zone 1.

H4l South of High Street, Ibstock

A tributary of the River Sence flows through this development site situated south of the High Street in Ibstock. However, the majority (90%) of the development site is situated within Flood Zone 1.

As Flood Zone 3b (similarly Flood Zone 3a and Flood Zone 2) does not extend across the whole of this site, through careful planning the More Vulnerable land use of housing may be directed into Flood Zone 1.

WS3 Hemington Quarry

The continuation of aggregate recycling facilities is proposed at Hemington, which is situated entirely within the functional floodplain (Flood Zone 3b) of the River Trent. The proposed development is Less Vulnerable and is considered unsuitable in this location. However, the retention of the inert waste recycling operation has been accepted for a temporary period providing flood risk is demonstrated as being acceptable or mitigation measures are put in place.

WS4 Lockington Quarry A

The continuation of aggregate recycling facilities is proposed at Lockington, which is situated within the floodplain of the River Trent. The proposed land use for this site is for an aggregate recyclying facility which is a Less Vulnerable development. The site is mainly situated within Flood Zone 3b, the breakdown of each flood zone as a percentage of the site area is as follows:

- Flood Zone 1 – 0%
- Flood Zone 2 – 3%
- Flood Zone 3a – 42%
- Flood Zone 3b – 55%

As Flood Zone 3b does not extend across the whole of this site, through careful planning the Less Vulnerable land use may be directed into Flood Zone 3a which would be acceptable; however the development may have to be scaled down to fit within Flood Zone 3a.

WS5 Lockington Quarry B

The proposed landfill area at Lockington Quarry B is also the site for proposed sand and gravel workings (MS1). The proposed landfill would be for inert waste and is classified as a More Vulnerable development. The majority of the site is situated within Flood Zone 3b (95%). Landfill is the preferred means for reclamation of the proposed extension to the mineral site, because the alternative of leaving the water spaces resulting from the sand and gravel extraction would be unlikely to be acceptable in terms of aircraft safety for Nottingham East Midlands Airport. However, land fill may be deemed to be appropriate within Flood Zone 3b providing flood risk mitigation measures are put in place.

### 5.3.4 Impacts of climate change on the Sequential Test Results

As identified previously, estimations of climate change impact upon flood risk is that the level of risk, or probability, will increase into the future.

There are no potential development sites within the climate change outline so there are no changes to the sequential test results.

## 5.4 Windfall Sites

Proposed development for "windfall sites" will by definition not derive from any potential development sites that have been assessed within Section 5.3. The Sequential Test will need to be carried out and, if necessary, the Exception Test at the planning application stage. Appendix C provides guidance notes to planners on how to use the sequential test for development sites including windfall sites.

# 6.0 SUSTAINABLE FLOOD RISK MANAGEMENT

## 6.1 Overview

Making Space for Water[20] sets out a new Government Strategy for flood and coastal erosion risk management. The vision of the strategy is that the concept of sustainable development will be firmly rooted in all flood risk management and coastal erosion decisions and operations. Flood and coastal erosion risk management will be clearly embedded across a range of Government policies, including planning, urban and rural development, agriculture, transport, and nature conservation and conservation of the historic environment.

Recent flood events have showed the devastating impact that flooding can have on lives, homes and businesses. A considerable number of people live and work in areas susceptible to flooding, and the ideal scenario would be to remove this development into areas not susceptible to flooding. However, it is recognised that this is not a practicable solution so measures should be put in place to minimise the risk to property and life posed by flooding. PPS25 requires that measures should mitigate flooding throughout the lifetime of any development and should therefore include any likely impacts from climate change.

## 6.2 Responsibility for Flood Risk Management

PPS25 states that *"there is no general statutory duty on the Government to protect land or property against flooding"*. However, the Government recognises the importance of safeguarding the wider social and economic wellbeing of the country. An overview of the key responsibilities with respect to the management of flood risk is provided below.

<u>Regional Planning Body</u>

The Regional Planning Body, for example, East Midlands Regional Assembly which should take flood risk into account in determining strategic planning considerations in the Regional Spatial Strategy, including the provision of future housing and transport infrastructure. A Regional Flood Risk Appraisal should identify the risk to strategic locations within the region.

<u>Local Planning Authority</u>

The Local Planning Authority is responsible for carrying out a Strategic Flood Risk Assessment to inform the allocation of land for future development, development control policies and sustainability appraisal. Local Planning Authorities have a responsibility to consult with the Environment Agency when making planning decisions.

Local authorities have certain permissive powers to undertake flood defence works under the Land Drainage Act 1991 on watercourses which have not been designated as Main Rivers and which are not within Internal Drainage Board areas. Local authorities can control the culverting of watercourses under S263 of the Public Health Act 1936.

[20] Making Space for Water. Taking forward a new Government strategy for flood and coastal erosion risk management in England, Defra, March 2005

Environment Agency

The Environment Agency has a statutory responsibility for flood management and defence in England. The Environment Agency supports the planning system through the provision of information and flood risk advice

At a strategic level, it provides the Regional Planning Body and the Local Planning Authority with advice on the preparation of Regional Flood Risk Appraisals and Strategic Flood Risk Assessments.

The Environment Agency will be consulted by Local Planning Authorities on all applications for development in flood risk areas and should contribute to their consideration by providing advice.

Under the Water Resources Act 1991, the Environment Agency has permissive powers for the management of flood risk arising from designated Main Rivers and the sea. The Environment Agency is also responsible for flood forecasting and flood warning dissemination, and for exercising a general supervision over matters relating to flood defence.

North West Leicestershire spans across two areas, Central and Eastern areas, of the Midlands Region. The Mease and Sence catchments which flow into the Upper Trent are the responsibility of Central area whilst the Trent and the Soar and their associated tributaries are the responsibility of the Eastern area.

British Waterways
British Waterways are responsible for maintaining critical infrastructure on the River Soar and ensuring locks etc. operate during flood events. British Waterways are also responsible for the Ashby Canal.

Severn Trent Water
Severn Trent Water is the sewerage undertaker for North West Leicestershire and is generally responsible for surface water drainage from development where this through adopted sewers. Severn Trent Water is responsible for ensuring the maintenance of drainage infrastructure through removal of blockages and undertaking improvement works to ensure flooding does not result from capacity problems.

Landowners and Developers

Landowners have the primary responsibility for safeguarding their land and other property against flooding. Riparian owners have the responsibility of maintenance of the watercourse which bound their property. Individual property owners and users are also responsible for managing the drainage of their land so that they do not adversely impact neighbouring land. Those proposing development are responsible for providing a site specific Flood Risk Assessment for submission with the planning application.

## 6.3 Strategic Flood Risk Management

Development along river corridors during the industrial age has resulted in large urban areas at risk of flooding. Historically, the management of flood risk was undertaken in a somewhat reactive manner, addressing problems on an ‘as needed’ basis in response to a flooding event through the construction of flood defence walls or embankments. It was recognised by Government that this approach was generally not a particularly cost effective solution and often failed to consider individual problem areas within the ‘bigger picture’ of the wider river system. The Environment Agency is now moving towards a more sustainable management of flood risk by steering away from the construction of raised defences and favouring solutions which work with natural processes.

The Environment Agency also endeavours to take a strategic approach to managing flood risk by considering flood risk on a catchment wide basis. Within the context of effective flood risk management therefore, the importance of influencing both the strategic planning process and development control as an outcome of these strategies is widely recognised as a key Environment Agency objective. For this reason, it is vital that the recommendations of the SFRA are consistent with the long-term strategy(s) for flood risk management within the District (catchment).

A number of flood risk management strategies have been undertaken of the Trent catchment encompassing North West Leicestershire District.

Trent Catchment Flood Management Plan

Catchment Flood Management Plans (CFMPs) are a planning tool through which the Environment Agency aims to "*work in partnership with other key decision-makers within a river catchment to explore and define long term sustainable policies for flood risk management*" [21].

The Trent Catchment Flood Management is currently at the Main Stage. The CFMP presents an outline of sustainable flood risk management for the Trent catchment for the next 50 and 100 years. Future policies for managing flood risk sustainably take into consideration the catchment characteristics, the likely impacts of climate change and the plans for future development. The CFMP will be used to guide the Environment Agency in their future investment policies and flood risk management activities for the Trent catchment.

The Environment Agency has published for consultation (August 2007) the Main CFMP document for the River Trent catchment. The CFMP's message on sustainable flood defences is clear;

*"Traditionally, flood risk management has focused on identifying engineered solutions to flood defence. Engineering solutions will continue to have an important role in managing flood risk, but will become increasingly pressured by future changes such as climate change, increasing urbanisation and changes to the way we manage land. The challenge for future flood risk management is to reduce the impact of these pressures by identifying opportunities for reducing surface run-off and increased capacity for floodwater storage, as well as appropriate development control and improved flood warning and response. The recognition of constraints to particular flood risk management options and areas of opportunity where flood management may improve environmental, social and economic value is essential to build consensus around future sustainable development".*

Fluvial Trent Strategy

The principal aim of the Fluvial Trent Strategy was to identify the preferred approach and potential solutions to sustainably manage flood risk along the Trent corridor over the next 50 years.

The Agency adopts a tiered approach to flood management with the large-scale plans, such as CFMPs at the highest level. CFMPs will deliver a broad-brush assessment of the risks, opportunities and constraints, including areas of uncertainty, associated with flood management policy. Following on from CFMPs, are the strategic studies, such as this one. Strategy Plans would normally be prepared for an entire river within the catchment. They would take forward the preferred policies identified from the

[21] Catchment Flood Management Plans Volume 1 Policy Guidance Environment Agency July 2004

CFMP and apply these for part of the catchment. The preferred approach is, therefore, to prepare a CFMP in advance of a strategy. However, the need to assess the current flood risk within the Trent Valley meant that this strategy commenced ahead of the CFMP.

A number of potential options have been considered including channel improvements, flood storage, removal of floodplain obstructions, flow diversion, raised defences, lands management and control structures, e.g. sluices and weirs. None of the preferred options taken forward were within the North West Leicestershire District; however, measures upstream may reduce the level of flood risk within the District.

National funding for flood defence is limited and the case for securing funding for flood alleviation schemes is anything but certain. Therefore, it is essential that planning decisions are made on the basis of the current (unmitigated) flooding regime.

## 6.4 Planning and Development Control

PPS25 creates a policy framework for North West Leicestershire District Council, Leicestershire County Council and the Environment Agency to contribute to a more sustainable approach to managing flood risk through the planning process. Opportunities for sustainable flood risk management that exist within the planning and development control process include:

- Considering flood risk at the early stages of the spatial planning process
- Ensuring planning decisions consider the implications of climate change
- Providing greater clarity to developers regarding which sites are suitable for developments of different types
- Developing local authority, developer and community-led intiatives for reducing flood risk and providing enhancement to the environment
- Ensuring direct and cumulative impacts of development on flood risk are considered and mitigated appropriately
- Considering flood risk and development on a catchment wide basis
- Developing integrated and sustainable developments which can deliver multiple benefits

In addition, certain conditions are imposed on planning applications which contribute to sustainable flood risk management, for example limiting surface water runoff from the site to greenfield runoff rates.

## 6.5 Mitigation Measures

### 6.5.1 Overview

In the first instance, the primary aim of Strategic Flood Risk Management is to avoid new development in areas of flood risk. The mapping outputs of this SFRA will help North West Leicestershire District Council achieve this aim when planning for the future of new development within their authority.

The sequential approach should be applied within development sites to locate the most vulnerable elements of a development in the lowest risk areas. However, avoidance of flood risk areas may not always be achievable or a policy of avoidance may prevent the economic and social regeneration of existing developments. In such instances, to meet the wider aims of sustainable development, it may be necessary to locate some development in areas at risk of flooding. In these circumstances careful consideration needs to be given to incorporating appropriate mitigation measures for managing and reducing the risk of flooding to the development. Approval of developments which include such measures should only be accepted providing the development passes the Sequential and Exception Tests and is consistent with the sustainability policies of North West Leicestershire District Council.

### 6.5.2 Objective of Flood Risk Mitigation

The objectives of flood risk mitigation measures are to:

- Reduce the probability of flooding to a development and consequently reduce the associate hazard to people occupying the development.
- Minimise the impact and damage that flood water may cause to a development and thus enable a faster recovery following a flood event.
- Ensure no adverse impacts resulting in increased flood risk to neighbouring sites.
- Wherever possible seek to provide an overall benefit in reducing flood risk for neighbouring sites.
- Be adaptable to future climate change scenarios

### 6.5.3 Sources of Information on Flood Risk Mitigation

There are several sources of information on potential mitigation measures, as follows:

- Flood Risk Assessment Guidance for New Development, Environment Agency R&D (FD2320)
- Development and Flood Risk – Guidance for the Construction Industry, CIRIA 624
- Flood resilient and resistant construction – guidance for new build, Department for Communities and Local Government (2007)
- Preparing for Floods, ODPM, 2003
- The SUDS Manual, CIRIA (C697)

### 6.5.4 Mitigation Measure Options

The Environment Agency R&D Guidance on Flood Risk Assessments for new development suggests that mitigation measures can be split into three types:

- Measures that reduce the physical hazard, e.g. through raised defences or flood storage
- Measures that reduce the exposure to the hazard, e.g. raise properties above flood levels
- Measures that reduce the vulnerability to the hazard, e.g. flood warning or emergency planning.

Consideration of mitigation measures can take place at a number of stages of the development process, these include;

- The Master Planning Stage
- The Outline Design Stage
- The Detailed and Internal Design Stage

The selection of appropriate mitigation measures depends on the requirements of the development and its sensitivity to flooding. Any mitigation measure selected should be sustainable in the future by taking into consideration the impact of climate change on flood risk. The residual risk of developing an area vulnerable to flooding with mitigation measures in place should also be considered.

Table 10 summarises the types of mitigation measures, their limitations and the stage of the development process when they should be considered. If the whole of the development site cannot be located away from areas of flood risk, ‘zoning’ of the development site should always be considered as the first mitigation measure. Only if ‘zoning’ of the site layout cannot fully mitigate the risk of flooding, should the remaining mitigation measures be considered. SUDS however, should always be considered for every new development site.

It is important to note that mitigation measures are only effective up to the magnitude of the flood event for which they are designed. If the design flood event is exceeded, then mitigation measures may not be effective. Exceedance of the design flood is an important consideration when employing mitigation measures for new development sites. Therefore, in some instances a combination of mitigation measures may need to be considered for a site. For example, flood resilience options should normally be included for all developments where significant mitigation measures have been included. This will provide the added benefit of ensuring a building can be quickly returned to use after an extreme flood event.

### 6.5.5 Emergency Planning

Emergency planning for extreme flood events is a key consideration for new developments which, having passed the Sequential and Exceptions Tests, are located in areas of flood risk. When preparing planning applications for such developments, developers should consult with the Environment Agency, emergency services and local resilience forums when developing emergency and evacuation plans. The outputs of the SFRA will provide a useful information base from which to initially consider viable routes for safe evacuation during flood events. At the site specific level, a more detailed appraisal of proposed evacuation routes may be required to confirm that the route is safe for the lifetime of the development.

A key part of emergency planning also involves raising public awareness to the potential risks and providing comprehensive information regarding flood warning and evacuation routes for members of the public to follow during extreme flood events. Both developers and North West Leicestershire District Council should give particular consideration to communication of flood warnings and advice to people with impaired hearing and/or sight and with restricted mobility.

North West Leicestershire District Council can also use the outputs from this SFRA to facilitate the development of emergency planning policies for existing developments at risk within their local authority by considering the feasibility and sustainability of key access routes within their administrative boundary and across boundaries into neighbouring authorities.

### 6.5.6 Flood Warning

Although North West Leicestershire District Council is responsible for developing emergency plans for their individual authority, the work undertaken by the Environment Agency in relation to flood warning is a key element which should be integrated into the process of developing such plans.

The Environment Agency’s National Flood Warning Centre is currently responsible for co-ordinating and issuing flood warnings via ‘Floodline’. The Environment Agency has developed a range of integrated catchment flood forecasting models for catchments which contain Flood Warning Areas. The main objective of this modelling is to improve the prediction of water levels at designated forecasting points and to assist in the process of issuing flood warnings. Consideration should be given to the estimated lead times which can be provided when developing strategies for emergency evacuation and response to flood events.

## 6.6 Surface Water Management

The planning system can act as an effective means of ensuring that all new developments manage surface water in a sustainable manner. Conventional surface water drainage systems have traditionally used underground pipe networks to efficiently convey water away from sites. In the past this has led to problems of downstream flooding, reductions in groundwater recharge and waste pollution incidents associated with surface water overwhelming combined sewers. Both '*Making Space for Water*' and the '*Water Framework Directive*' have highlighted the need for an improved understanding and better management of how our urban environments are drained.

PPS25 requires that a site-specific flood risk assessment is undertaken for all sites including those in Flood Zone 1 with an area greater than one hectare to ensure that downstream flooding problems are not made worse by surface water runoff from the development.

Surface water drainage systems for a development should ensure that there is little or no residual risk of flooding for events in excess of the return period for which the sewer system on the site is designed.

For previously undeveloped sites the rate of runoff from the development sites should be no greater than the existing (greenfield) rate of runoff from the site

For developments on previously developed (brownfield) sites the rate of runoff should not exceed the runoff of the site in its previously developed condition. However, developers should be encouraged to reduce runoff from these developments to 20% below previous rates wherever practicable to accommodate climate change.

As the upper part of several catchments are within North West Leicestershire, e.g. River Mease, River Sence and Grace Dieu Brook the District Council has responsibility to ensure development does not increase flows downstream in neighbouring authorities.

Sustainable Urban Drainage Systems (SUDS) aim to mimic the natural drainage processes whilst also removing pollutants from urban runoff at the source before entering a watercourse. There are a wide range of SUDS techniques, including green roofs, permeable paving, swales, detention basins, ponds and wetlands. The different types of SUDS and where they can be used appropriately within North West Leicestershire are discussed in Section 7.

***Table 10 - Summary of Mitigation Measures (Source of Text PPS25 Practice Guide)***

| Mitigation Option | Description | Examples | Development Stage | Limitations |
|---|---|---|---|---|
| Site Zoning/ Layout | The sequential approach can be applied within development site boundaries to locate the most vulnerable elements of the development in the areas of lowest risk. | Locating flood-compatible development, such as areas of open space and car parking in areas at higher risk and reserving lower risk areas for more vulnerable land use types such as housing. | Master Planning Stage | The spatial planning of developments sites may not always be achievable in line with a sequential approach for urban Brownfield sites where the location of existing development and access routes can prevent zoning of development land use in line with flood risk probability. |
| Modification of Ground Levels | The probability of flooding can be mitigated through the modification of ground levels to raise developments above the flood level or at least reduce the depth of predicted flood water. | Land raising parts of a development sites using material, either from other parts of the site or imported to the site from other locations. | Master Planning and Outline Design Stage | Raising ground levels may not be viable if existing buildings or access routes at ground level need to be maintained.<br>Care is needed to avoid the formation of islands which would become isolated in flood conditions and to ensure there is safe access.<br>Land raising must be accompanied by level-for-level compensatory provision of flood storage either on- or off-site.<br>This option can prove costly if large volumes of material need to be moved or if fill material needs to be imported to the site from other locations. |
| Flood Walls & Embankments | Construction of engineered defences to prevent flood water entering a development site | Sheet pile walls, earth embankments, sea walls with wave return, revetments. | Master Planning and Outline Design Stage | New defences for developments should only be considered if fully funded and maintained by the developer and if the residual risk behind the development is appropriate to the land use proposed.<br>Compensatory flood storage should be provided if new flood defences have been provided to allow development.<br>Flood defence mitigation options can be costly and will require ongoing investment for maintenance. Developers proposing defences should also ensure that the defences can adapt to future climate change scenarios to maintain the minimum standard of protection required by PPS25 for the life time of the development.<br>New defences must not increase flood risk to offsite third parties, and must be clearly demonstrated. |
| Flood Storage | The provision of upstream flood storage, either on or off the line of a river or watercourse, may be an effective measure to manage water levels at and downstream of a development site. | Flood storage reservoirs, controlled washlands, flood storage wetlands. Such options can also provide ecological and habitat benefits. | Master Planning and Outline Design Stage | Such options can involve significant land take which will need to be secured by the developer. If operational controls are required for such options consideration needs to be given to how this will be managed over the lifetime of the development. The longer term maintenance of the flood storage options will also need to be addressed from both a funding and operational perspective. |
| Building Design | Buildings can be designed such that the ground floor comprises flood compatible uses which are resilient to flood water and the associated damage caused. Residential and other people intensive uses are then located on the first floor upwards.<br><br>Single-storey residential development and basements should not be considered in flood risk areas as such developments are generally more vulnerable to flood damage and occupants do not have the opportunity to retreat to higher floor levels. | Water compatible uses for the ground floor can include open plan public spaces, car parking and or utility areas. Provision of private garages or other enclosed private spaces should be avoided due to possible vehicle damage, pollution from stored material and a reduction in flow conveyance. | Detailed Design Stage | Where developments incorporate open space beneath the occupied level, measures such as legal agreements need to be in place to prevent inappropriate use or alteration of the ground floor that would impede flood conveyance or reduce flood storage.<br>Safe access to higher ground, above the flood level, should be made available for people to evacuate all buildings where the habitable level is raised above the flood level.<br>In areas of high flood flow velocity buildings should be structurally designed to withstand the expected water pressures, potential debris impacts and erosion which may occur during a flood event. |
| Temporary, Demountable or Operational Defences | Flood defences which require human intervention to ensure successful operation during a flood event. | Flood barriers and gates | Detailed Design Stage | These measures are unlikely to be suitable as the only mitigation measure as it is not usually appropriate to design a new development to rely on demountable or temporary flood defences to manage flood risk, unless such measures are proposed solely to manage residual flood risk to individual properties.<br>For water-compatible and less vulnerable land uses, such measures may be appropriate where temporary disruption is acceptable and appropriate flood warning to activate the defences is provided. |
| Flood Resilience | External and internal building design, fixtures and fittings which ensure that the building can be quickly returned to use after a flood. | Raising electrical sockets above the predicted flood level. Wet proofing wall and floor furnishings using materials such as tiles and paint. | Detailed and Internal Design Stage | Such measures are unlikely to be suitable as the only mitigation measure to manage flood risk, but they may be suitable where<br>• disruption to water-compatible and less vulnerable uses is acceptable and appropriate flood warning is provided.<br>• there are instances where the use of an existing building is to be changed and it can be demonstrated that no other measure is practicable. |
| SUDS | A sequence of management practices and control structures, designed to drain water in a more sustainable manner than some conventional techniques. Typically these are used to attenuate run-off from development sites. | There are a number of engineered and landscape vegetated types of SUDS options. | Outline and Detailed Design Stage | Issue which require early consideration when proposing SUDS include;<br>Land Take: is there sufficient land available for the options proposed?<br>Adoption and Maintenance: Who will fund, own and maintain the systems once installed, for the operational lifetime? This issue can often be secured through a planning condition for simple schemes or through a Section 106 agreement. |

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# 7.0 FLOOD RISK MANAGEMENT FOR NORTH WEST LEICESTERSHIRE

## 7.1 Funding of Flood Defence Works

Where proposed developments include the provision of new flood mitigation measures, these should generally be funded wholly by the developer. Developers proposing new mitigation measures which solely benefit new development should not call on public resources as a means of funding.

North West Leicestershire District Council may wish to consider entering into an agreement under Section 106 of the Town and Country Planning Act 199031 to ensure that the developer carries out the necessary works and that future maintenance commitment are met. They may also apply planning conditions which would require completion of the necessary works before the rest of the development can proceed.

Where the mitigation measures proposed provide benefit to the wider community, or where the proposed works include upgrade or replacement of existing defences or flood alleviation schemes, it may be reasonable for the developer to contribute a proportion of the funding in partnership with the operating authority responsible for the existing works.

It should be noted that the construction of new flood defences to enable a development to proceed are not normally favoured / acceptable to the Environment Agency.

## 7.2 Raising Flood Defences to 1% AEP Standard of Protection

One of the objectives of the North West Leicestershire SFRA is to provide information regarding current and future investment requirements for flood defences. In order to identify locations where shortfalls in defence standards exist, appropriate defence standards need to be determined. PPS25 states that the minimum acceptable standard of protection for new developments should be 100 years (1% AEP) for fluvial flooding. The extent and cost of works required to raise the flood defence standard to 1% (100 year) has been calculated.

The Environment Agency Unit Cost Database was originally developed in 2001 based on historic information on capital projects completed within England and Wales. Since 2001 it has been updated with more recently completed projects and this information is provided in a Flood Risk Management Estimating Guide[22].

For each of the raised defences with a design standard of less than 1% AEP mentioned in Table 2 in Section 3.7.2 a cost of raising the standard of protection has been calculated based on the Unit Cost Database for flood embankments and these are summarised in Table 11.

Raising the height of minor embankments (10 year standard of protection) is not a sustainable option, as detailed in Section 6, and would result in large volumes of lost floodplain. Therefore, only defences with a standard of protection greater than or equal to 25 years have been considered.

[22] Flood Risk Management Estimating Guide – Unit Cost Database 2007, Environment Agency, October 2007

*Table 11 – Estimated Costs for Raising the Standard of Protection of Flood Defences to 1% AEP*

| Maintainer | Asset Description | Asset Location | Design SoP (yrs) | Watercourse | Length | Required Height | Required Volume of fill | Cost (£)** |
|---|---|---|---|---|---|---|---|---|
| private | Old Road Bridge Abutment | Old Packington Road Bridge | 50 | Gilwiskaw Brook | 28.00 | 0.30 | 336 | £30,000 |
| private | Embankment. | Dismantled railway | 25* | Grace Dieu Brook | 177.10 | 0.50 | 2125 | £175,000 |
| private | Embankment | U/s of Ashby Road | 25* | Grace Dieu Brook | 136.40 | 0.50 | 1637 | £150,000 |
| local authority | Railway embankment. | D/s of the City of Three Waters | 25* | Grace Dieu Brook | 242.30 | 0.50 | 2908 | £250,000 |
| local authority | Embankment | D/s of Coverdale | 25* | Grace Dieu Brook | 83.00 | 0.50 | 996 | £100,000 |
| local authority | Raised wall. | Coverdale | 25* | Grace Dieu Brook | 26.20 | 0.50 | 314 | £250,000 |
| Environment Agency | Embankment. | A50, Lockington. | 25* | Lockington Brook | 549.30 | 0.50 | 6592 | £400,000 |
| private | Embankment. | U/S of A50, nr Lockington | 25* | Lockington Brook | 463.10 | 0.50 | 5557 | £350,000 |
| Environment Agency | Wall | Lockington | 25* | Lockington Brook | 130.10 | 0.50 | 1561 | £125,000 |
| Environment Agency | Embankment. | Along the M1 | 25* | Hemington Brook | 940.20 | 0.50 | 11282 | £675,000 |

* Standard of Protection of Defences estimated

**30% added for Contractors costs

## 7.3 Applicability of the use of SUDS

PPS25 states that Local Authorities should prepare and implement planning strategies that help to deliver sustainable development, by using opportunities offered by new development to reduce the causes and impacts of surface water flooding. By implementing policies to encourage developers to incorporate SUDS wherever possible, Local Authorities can help to mitigate the impacts that development has on surface water runoff rates and volumes.

Figure 12 provides information relating to the spatial variation of permeability across North West Leicestershire. This information can be used as a first estimate of the suitability of different types of SUDS within North West Leicestershire as shown in Table 12.

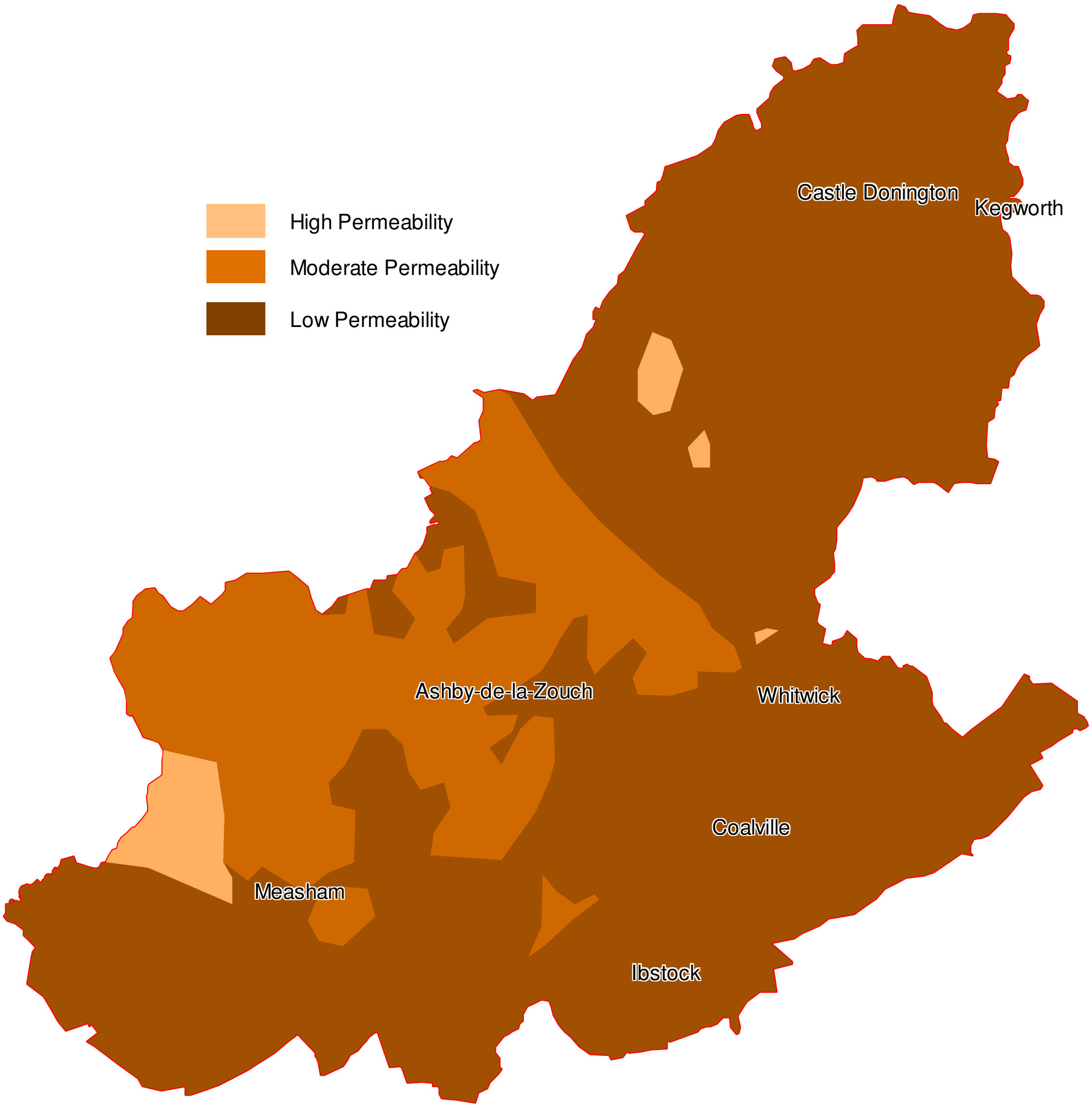


***Figure 12 – Permeability across North West Leicestershire***

The general soil type within North West Leicestershire is 'loamy'. This soil type is moderately well drained, but it can be seasonally waterlogged. The catchment run-off can, therefore, be quite variable, and when waterlogged will result in a rapid response with high run-off rates

***Table 12 - Suitability of SUDS***

| Permeability | Indicative Suitability of SUDS Techniques |
|---|---|
| High Permeability | Infiltration and Combined Systems |
| Moderate Permeability | Infiltration and Combined Systems |
| Low Permeability | Attenuation Systems |

It is important to note that the above assessment of the spatial suitability of SUDS is an indicative estimate and should be confirmed at the site specific level, using ground investigation data.

*Infiltration Systems*

Infiltration systems allow surface water to discharge directly into the ground. These systems are only appropriate where ground conditions permit; 1) a suitable water acceptance potential and 2) in locations where groundwater recharge will not adversely affect drinking water aquifers as identified by the Environment Agency's source protection zones, available on their website http://www.environment-agency.gov.uk. Such systems may include:

- Permeable surfaces
    - Gravel
    - Permeable Paving
    - Block Paving with voids
    - Grassed areas

- Sub Surface Infiltration
    - Filter Drains
    - Geocellular Systems
    - Soakaways

*Attenuation Systems*

If ground conditions cannot support infiltration systems, surface water may need to be attenuated using measures to store surface water. Attenuation systems, if designed at ground level, have the potential to take up large areas of development sites. Early consideration of such constraints is therefore essential. Attenuation systems may include:

- Landscaped
    - Detention Basins
    - Balancing Ponds
    - Retention Ponds
    - Wetlands
    - Lagoons

- Engineered
    - Underground Tanks
    - Ornate Water Features
    - Rainwater Harvesting
    - Green Roofs
    - Oversized Pipes

*Combined Systems*

SUDS designs for most sites can include a combination of infiltration and attenuation systems and they have been categorised above according to the dominant process. Other forms of SUDS which can provide more balanced benefits of infiltration and attenuation include:

- Swales
- Filter Strips

## 7.4 Packington Flood Storage Feasibility

### 7.4.1 Background

Residents of Packington village have been concerned for several years about the risk of flooding from Gilwiskaw Brook as it flows through the village. Anecdotal evidence from residents suggests that occurrence of flooding may have become more frequent in the last 10 years or more but there are no historical records available to confirm this. The Environment Agency (2001) and Packington Parish Council (2003) have undertaken pre-feasibility studies to address the potential flooding problems and to identify possible mitigation measures. The study undertaken as part of this SFRA is to identify potential flood storage options for reducing flood risk in Packington village whilst providing storage to attenuate runoff from future developments upstream in Ashby-de-la-Zouch.

The detailed hydrological and hydraulic modelling along with the flood storage options are provided in Appendix D, with the FEH Calculation Record and modelled stage and flows provided in Appendix E and F respectively.

### 7.4.2 Flood Storage Options

Potential flood storage was identified upstream of the A42 in the Nook Farm area and downstream of the A42 in the rural area before Gilwiskaw Beck reaches Packington. Two scenarios were tested using the model which utilised the area identified at Nook Farm as seen in Figure 4 below. To allow for this area, reservoir units were added to the 1% AEP model and an orifice unit was used to restrict flow at the A42.

The two different scenarios tested had differing restrictions on the flow and they were undertaken for the 1% AEP and 1% AEP plus climate change for the current development situation. However, for the purpose of the SFRA, there is a need to identify whether the flood storage option is suitable to provide attenuation from increased urban development whilst providing some flooding protection to Packington village.

It is anticipated that development of the Gilwiskaw catchment will continue in the future through proposed development considered by developers and North West Leicestershire in the Local Plan and Urban Housing Potential Study along with infill development and paving of grassed areas. For the purposes of this study it is assumed that urban coverage will increase by 10% and that it will largely be on greenfield land and therefore will result in excess surface water runoff.

### 7.4.3 Results of Flood Storage

The results of modelling the flood storage options for the 1% AEP showed that there was additional benefit in restricting the flow to 5 cumecs as it reduced the depth of flooding through Packington particularly along Mill Street by up to 200mm. The preferred option was therefore Scenario 2 which limited flows in Packington to approximately a 10 year return period and limited flood risk to only 2 properties. The scenario testing the flood storage capacity required to attenuate additional runoff from urban development showed that an additional storage volume of 1,542m$^3$ is required for the Climate Change scenario.

Although it is possible to provide attenuation of additional runoff within the Nook Farm flood storage area, the increase in flows within Gilwiskaw Brook may cause flooding to properties upstream of the flood storage basin. The water levels increase by 100 to 150mm upstream of the flood storage basin.

Flood storage facilities are classified as impoundments when constructed above ground level and as such if they exceed 25,000m$^3$ they would come under the jurisdiction of the Reservoir Act 1975. The Reservoir Act requires a rigorous inspection and monitoring regime conducted by a qualified Reservoir Panel Engineer. It is recommended that any proposed flood storage facility is less than 25,000m$^3$. However, restricting the volume of flood storage to 25,000m$^3$ would result in 9 properties at risk of flooding in Packington and a maximum depth of flood water of 0.6m in Mill Street. It is possible to provide an additional flood storage area upstream of Packington but downstream of the A42; thereby limiting the size of the flood storage area upstream of the A42.

### 7.4.4 Conclusions

There is sufficient area upstream of the A42 to provide attenuation of existing runoff and potential runoff from development. With a flood storage volume of 39,762m$^3$ which attenuates the 1% AEP plus climate change and urban development, flow within Packington is restricted to 5m$^3$/s and flooding is limited to 2 properties with some flooding of roads and gardens. Mapping of flood outlines has been undertaken using Lidar data. A more accurate assessment of the risk to these two properties should be undertaken by comparing the flood levels with the threshold levels of properties. The flood storage option will reduce the risk to these two properties in terms of depth and velocity of flood water but additional flood protection measures may be required.

It is considered that the level of protection to Packington is very small in relation to the cost of the design of the storage area, site investigation, land acquisition and construction works along with the maintenance of the flood storage area following construction. However, if the council wants to adopt a “Developer Pays” principle then a solution may be forthcoming by permitting new development in the area.

In addition, the flood storage area had to be located downstream of Ashby to enable the maximum attenuation of flows upstream of Packington. There is no land available further upstream in Ashby. However, in providing attenuation downstream of development within Ashby, any development within Ashby itself will increase flows within Gilwiskaw Brook before it is attenuated within the flood storage basin. Increased flows in Gilwiskaw Brook may cause localised flooding within Ashby. Therefore, one large flood storage area is not considered a feasible option for attenuating runoff from several developments. Instead, attenuation should be provided for each of the development sites on the site itself to ensure there is no increase in flood risk downstream. Attenuation of developments on a case by case basis however will not provide the flood protection afforded by the flood storage option considered here which aims to alleviate existing flood risk whilst providing additional protection from flooding as a result of increased urban development and climate change.

It is recommended that a combination of flood storage areas both at the development site and at the A42 is considered to alleviate flood risk in Packingon whilst attenuating runoff from proposed development.

## 7.5 Development Control

Advice notes for developers for undertaking Site Specific Flood Risk Assessments within North West Leicestershire are provided within Appendix G.

# 8.0 CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

1. This SFRA Report provides an overview of the planning context in relation to flood risk and development within North West Leicestershire. Flood risk is considered within each of the tiers of planning policy; nationally within the Planning Policy Statements, regionally within RSS8 and locally within the Local Plan, Structure Plan and LDF.

2. Data has been collected through consultation with North West Leicestershire District Council. Leicestershire County Council, Environment Agency, Severn Trent Water, the Coal Authority and British Waterways. The data collected has provided information on all sources of flood risk, flood defences, flood warning, land allocations, geology and topography.

3. The primary source of flood risk in North West Leicestershire is fluvial flooding. The north and east of the District is vulnerable from the River Trent and the River Soar, both independently and, in wider flood events, concurrently. The south and west of the District is at risk of fluvial flooding from the River Mease and the River Sence.

4. North West Leicestershire is also at risk from flooding from sewers, canal infrastructure failure, surface water and groundwater rising in former coal mining areas.

5. Flood defence embankments are in place along the River Trent and the River Soar where the rivers form the North West Leicestershire District boundary. The flood defences were constructed in the 1960s and early 1970s and in some places provide protection from flooding up to an annual probability of 1%. There are formal defences along Gilwiskaw Brook, Hooborough Brook, River Mease and River Sence ranging from a standard of protection of 20% AEP to 2% AEP.

6. In addition to the formal defences there are numerous informal defences in private ownership, for example on Grace Dieu Brook, where responsibility for maintenance lies with the riparian owner and the standard of protection and maintenance regimes are unknown.

7. In addition to flood defences to reduce the probability of flooding, flood warning has been in operation in the Trent catchment for a number of years as a means of reducing the impacts of flooding. Flood Warning is provided on the River Mease, River Soar and the River Trent. In addition, North West Leicestershire is covered by general early alerts to possible flooding, known as Flood Watches.

8. Climate change is expected to have an influence on future flood risk. The expectations are that winter floods will happen more often and in urban areas flooding from thunderstorms will be more regular and more severe. Climate change has an impact on the number of properties at risk within North West Leicestershire and in particular on the depth of flooding.

9. Breach analysis of the flood defences protecting property within Castle Donington, Hemmington, Lockington and Kegworth for a 1% AEP has shown that there is a significant flood hazard in close proximity to the flood defence. At a further distance (>200m) from the breach the depth and velocity of the flood water are much lower and the flood hazard is considered to be low.

10. The majority of the flood defences within North West Leicestershire have a standard of protection of less than 2% AEP (50 year) with some only having a standard of protection of 10% AEP (10 year). These flood defences will be easily overtopped and out of bank flow will occur in a manner almost as if no defences existed.

11. A Sequential Test approach has been undertaken using the potential development sites identified within the North West Leicestershire Local Plan, the Urban Capacity Study and Leicestershire Minerals and Waste Development Frameworks.

12. In total, there are 58 potential development sites within the District Boundary. 42 of these sites are identified to fall within Flood Zone 1 'Low Probability' and therefore all uses of land/development types would be appropriate. However for developments on sites of 1 Ha or larger a site-specific Flood Risk Assessment is required.

13. No sites are identified to be within Flood Zone 2 'Medium Probability'.

14. The remaining 12 sites are all identified to fall within Flood Zone 3, of which 6 are within Flood Zone 3a 'High Probability' and the remaining 10 within Flood Zone 3b 'Functional Floodplain'. In Zone 3a Less Vulnerable and Water Compatible uses are deemed appropriate. More Vulnerable and Essential Infrastructure require the Exception Test to be passed and Highly Vulnerable development should not be permitted. In Zone 3b only Water Compatible uses are deemed appropriate. Essential Infrastructure requires the Exception Test to be passed. All other uses should not be permitted.

15. "Windfall sites" are potential development sites which have not been determined through the Local Plan, housing availability studies, etc. and have not been considered as part of this SFRA. The Sequential Test will need to be carried out for windfall sites and, if necessary, the Exception Test at the planning application stage.

16. Mitigation measures for future development within North West Leicestershire can include measures that reduce the physical hazard, e.g. through raised defences or flood storage; measures that reduce the exposure to the hazard, e.g. raise properties above flood levels or measures that reduce the vulnerability to the hazard, e.g. flood warning or emergency planning.

17. Surface water drainage systems for a development should ensure that there is little or no residual risk of flooding for events in excess of the return period for which the sewer system on the site is designed. For previously undeveloped sites the rate of runoff from the development sites should be no greater than the existing (greenfield) rate of runoff from the site. For developments on previously developed (brownfield) sites the rate of runoff should not exceed the runoff of the site in its previously developed condition. However, developers should be encouraged to reduce runoff from these developments to below previous rates wherever practicable.

18. The cost of raising the standard of protection has been calculated based on the Unit Cost Database for flood embankments and this totals approximately £2.5m for defences with at least a current 1 in 25 year standard of protection.

19. The permeability of the soil within North West Leicestershire is mainly low with some small areas or medium and high permeability soils. The implementation of SUDS as part of developments is thus largely restricted to attenuation systems. However, the spatial suitability of SUDS is an indicative estimate and should be confirmed at the site specific level, using ground investigation data.

20. A feasibility study has been undertaken to identify potential flood storage areas to reduce flood risk in Packington. The study has found that there is sufficient area upstream of the A42 to provide attenuation of existing runoff and potential runoff from development. With a flood storage volume of 39,762$m^3$ which attenuates the 1% AEP plus climate change and urban development, flow within Packington is restricted to 5$m^3$/s and flooding is limited to 2 properties with some flooding of roads and gardens.

21. It is considered that the level of protection to Packington is very small in relation to the cost of the design of the storage area, site investigation, land acquisition and construction works along with the maintenance of the flood storage area following construction. However, if the council wants to adopt a "Developer Pays" principle then a solution may be forthcoming by permitting new development in the area.

22. The proposed flood storage area is downstream of any potential development sites within Ashby and any development within Ashby itself will increase flows within Gilwiskaw Brook before it is attenuated within the flood storage basin. Increased flows in Gilwiskaw Brook may cause localised flooding within Ashby. Therefore, one large flood storage area is not considered a feasible option for attenuating runoff from several developments. Instead, attenuation should be provided for each of the development sites on the site itself to ensure there is no increase in flood risk downstream. Attenuation of runoff from future developments on a case by case basis however will not provide the flood protection to Packington afforded by the flood storage option considered here which aims to alleviate existing flood risk whilst providing additional protection from flooding as a result of increased urban development and climate change.

## 8.2 Recommendations

1. There is limited information available on sewer flooding and in particular whether flooding is a result of limited capacity issues or localised blockages or sewerage infrastructure. Data should be made available by Severn Trent Water in order for a more thorough assessment to be made of the risk to a particular development site.

2. There needs to be a consistency in how runoff from development is attenuated. Connecting new developments into the Severn Trent Water drainage system is not sustainable as surface water sewers discharge into the watercourses. Developers should be encouraged to attenuate surface water runoff on previously developed sites by 20% on the site so it does not put pressure on the existing drainage system or increase runoff into watercourses via the sewer network and takes into consideration climate change.

3. For developments within Flood Zone 1 and less than 1 Hectare in area, developers should be encouraged to develop sustainably and where possible limit surface water runoff by encouraging the use of permeable paving, rainwater harvesting, green roofs, etc. This will reduce the cumulative impacts of minor development on runoff into the watercourses.

4. There is a need to assess whether there is any critical infrastructure, e.g. hospitals, emergency services, etc within the floodplain for emergency planning purposes and to ensure there is access and egress during a flood event.

5. It is recommended that a combination of flood storage areas both at the development site and at the A42 is considered to alleviate flood risk in Packingon whilst attenuating runoff from proposed development.

6. This SFRA does not replace the need for site specific flood risk assessments. A greater level of detail should be provided by these assessments with respect flood risk and any protection afforded to the site, including from informal flood defences. Consideration should be given to the proportion of the site located within specific PPS25 Flood Zones and the implications of this upon the development layout of the site. This process will allow planning of sites to place higher vulnerability uses within lower risk areas. Where required, the Exception Test should be undertaken as part of the site specific FRA. Site specific FRAs are required for all sites over 1 hectare in size and for all sites located with Flood Zones 2, 3a and 3b.

7. The SFRA has been produced based on current understanding of flood risk and existing and available flood risk information. In time, as Environment Agency studies are complete and further flood risk understanding is developed the

information within this document will become outdated, Therefore, it is important that the SFRA is reviewed and updated at regular intervals to incorporate this information.

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# Appendix B　Sequential Test

Potential development site Land Use Classifications and the Sequential Test Results

| Site Code | Proposed Development Site Name | Flood Zone | More Vulnerable | | Less Vulnerable | | | | | Water Compatible |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Housing | Landfill | Industrial | Offices | Storage and Distribution | Mineral Working | Waste Management | Sand and Gravel workings |
| J3a | Swainspark Industrial Estate, Occupation Road, Albert Village | FZ3a | | | ✓ | ✓ | ✓ | | | |
| J3b | Smisby Road, Ashby de la Zouch | FZ1 | | | ✓ | ✓ | ✓ | | | |
| J3c | Extension to Hilltop Industrial Estate, Bardon | FZ3b | | | ✓ | ✓ | ✓ | | | |
| J3d | South of Coalville Brickworks | FZ1 | | | ✓ | ✓ | ✓ | | | |
| J3f | South of Trent Lane, Castle Donington | FZ3a | | | ✓ | ✓ | ✓ | | | |
| J3g | Extension to Westminster Estate, Measham | FZ3b | | | ✓ | ✓ | ✓ | | | |
| J3h | Former Walton Wat Drift Mine, Oakthorpe | FZ1 | | | ✓ | ✓ | ✓ | | | |
| J13 | Castle Donington Power Station | FZ3b | | | | | ✓ | | | |
| H4a | Leicester Road, Ashby de la Zouch | FZ3a | ✓ | | | | | | | |
| H4b | East of Leicester Road, Ashby de la Zouch | FZ3b | ✓ | | | | | | | |
| H4d | Broom Leys Road, Coalville | FZ1 | ✓ | | | | | | | |
| H4e | Wentworth Road, Coalville | FZ1 | ✓ | | | | | | | |
| H4g | Grange Road, Hugglescote | FZ3b | ✓ | | | | | | | |
| H4h | Brooks Lane, Whitwick | FZ1 | ✓ | | | | | | | |
| H4i | North of Park Lane, Castle Donington | FZ1 | ✓ | | | | | | | |
| H4j | Station Road, Castle Donington | FZ3a | ✓ | | | | | | | |
| H4k | High Street, Ibstock | FZ3a | ✓ | | | | | | | |
| H4l | South of High Street, Ibstock | FZ3b | ✓ | | | | | | | |
| H4o | Main Street, Oakthorpe | FZ1 | ✓ | | | | | | | |
| A709 | 2-2a Derby Road, Ashby | FZ3a | ✓ | | | | | | | |

| Site Code | Proposed Development Site Name | Flood Zone | More Vulnerable | | Less Vulnerable | | | | | Water Compatible |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Housing | Landfill | Industrial | Offices | Storage and Distribution | Mineral Working | Waste Management | Sand and Gravel workings |
| C1 | Land between No.s 125-149 Grange Road | FZ1 | ✓ | | | | | | | |
| C3 | Land at St. Marys Avenue | FZ1 | ✓ | | | | | | | |
| C9 | Council Depot, Highfield Street, Coalville | FZ1 | ✓ | | | | | | | |
| C11 | Land south of Forest Road | FZ1 | ✓ | | | | | | | |
| C12 | Land adjacent to Minnesota's | FZ1 | ✓ | | | | | | | |
| C17 | Church Lane, Whitwick | FZ1 | ✓ | | | | | | | |
| C20 | Pumping Station, Hall Lane | FZ1 | ✓ | | | | | | | |
| C23 | Land off Ashby Road | FZ1 | ✓ | | | | | | | |
| C27 | Part of Snibston Discovery Park | FZ1 | ✓ | | | | | | | |
| C700 | Enterprise House, Ashby Road, Coalville | FZ1 | ✓ | | | | | | | |
| C705 | Land at Ashby Road, Coalville | FZ1 | ✓ | | | | | | | |
| C707 | Land adjacent to Discovery Park, Ashby Road, Coalville | FZ1 | ✓ | | | | | | | |
| C801 | Land at Cropston Drive, Coalville | FZ1 | ✓ | | | | | | | |
| CD7 | Land East of High Street | FZ1 | ✓ | | | | | | | |
| CD702 | Donington Mill, Station Road, Castle Donington | FZ1 | ✓ | | | | | | | |
| IB2 | Land off High Street, Ibstock | FZ1 | ✓ | | | | | | | |
| IB3 | Poplar Farm, High Street | FZ1 | ✓ | | | | | | | |
| IB6 | Land between 112 and 128 Melbourne Road | FZ1 | ✓ | | | | | | | |
| K2 | Land east of Packington Hill | FZ1 | ✓ | | | | | | | |
| K5 | Computer Centre, Derby Road, Kegworth | FZ1 | ✓ | | | | | | | |
| K6 | Land to the rear of 'the computer centre', Derby Rd, Kegworth | FZ1 | ✓ | | | | | | | |
| K703 | Brookes Machine Tools Ltd, 2 Derby Road, Kegworth | FZ2 | ✓ | | | | | | | |

| Site Code | Proposed Development Site Name | Flood Zone | More Vulnerable | | Less Vulnerable | | | | | Water Compatible |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Housing | Landfill | Industrial | Offices | Storage and Distribution | Mineral Working | Waste Management | Sand and Gravel workings |
| K705 | Slack and Parr Ltd, Long Lane, Kegworth | FZ3 | ✓ | | | | | | | |
| M1 | Land east of High Street, Measham | FZ1 | ✓ | | | | | | | |
| M2 | Former Youth Club and Land West of High Street, Measham | FZ1 | ✓ | | | | | | | |
| M3 | Land at rear of 34-54 Chapel Street, Measham | FZ1 | ✓ | | | | | | | |
| M6 | Land off New Street, Measham | FZ1 | ✓ | | | | | | | |
| M8 | Land off New Street, Measham | FZ1 | ✓ | | | | | | | |
| M702 | Land North East of Atherstone Road, Measham | FZ1 | ✓ | | | | | | | |
| M703 | 3a New Street Measham | FZ1 | ✓ | | | | | | | |
| WS1 | Swainspark | FZ1 | | | | | | | ✓ | |
| WS2 | Donnington Island | FZ1 | | | | | | ✓ | | |
| WS3 | Hemington | FZ3b | | | | | | | ✓ | |
| WS4 | Lockington A | FZ3b | | | | | | | ✓ | |
| WS5 | Lockington B | FZ3b | | ✓ | | | | | | |
| WS6 | Little Wigston | FZ1 | | | | | | | ✓ | |
| MS1 | Lockington (mineral) | FZ3b | | | | | | | | ✓ |
| MS2 | Ibstock | FZ1 | | ✓ | | | | | | |

Note: ✓ represents the type of development proposed
Red indicates Development is inappropriate, Amber indicates the Exception Test is required and Green indicates the development is appropriate
The Flood Zone represented within column 3 is the 'worst case' Flood Zone on the site

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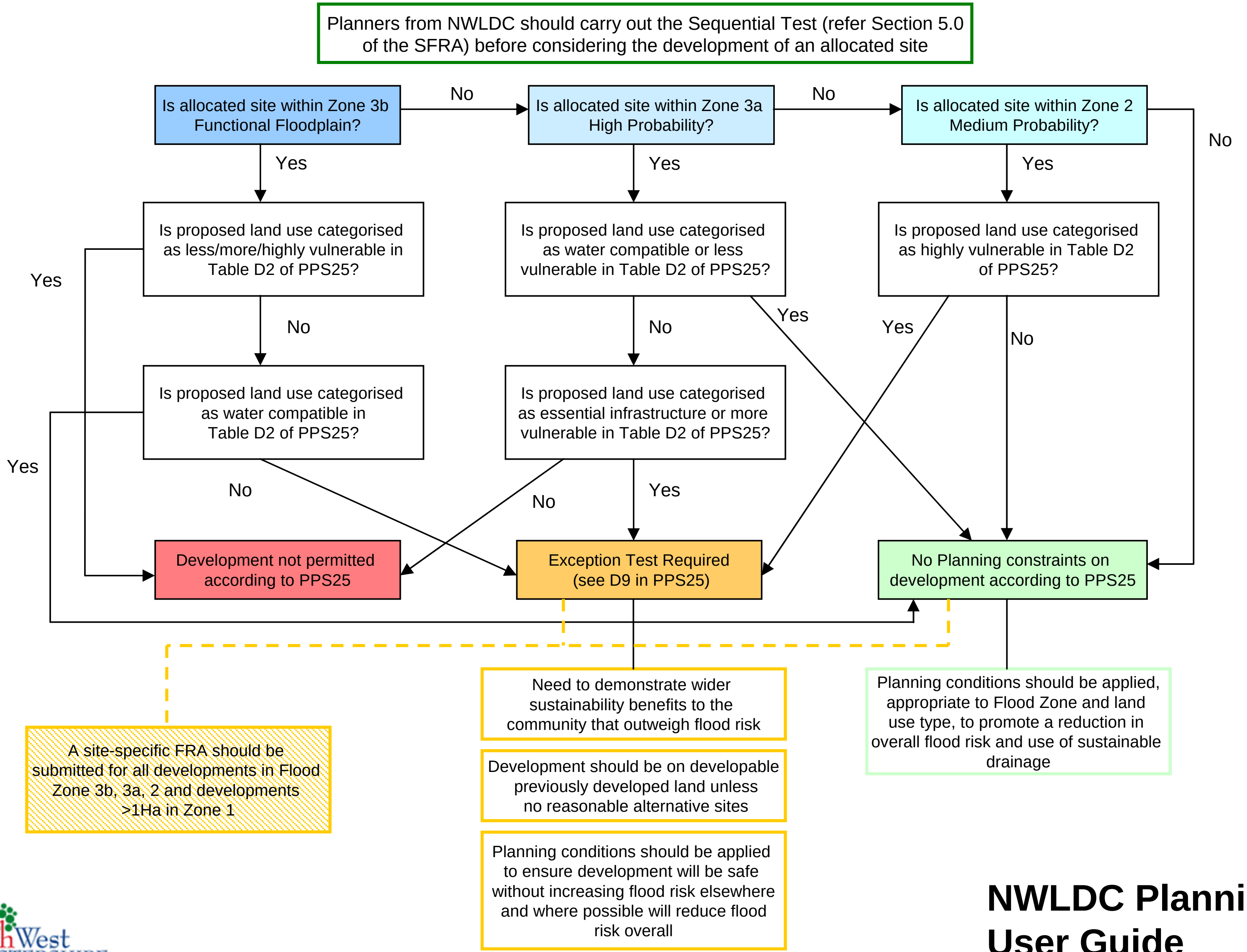
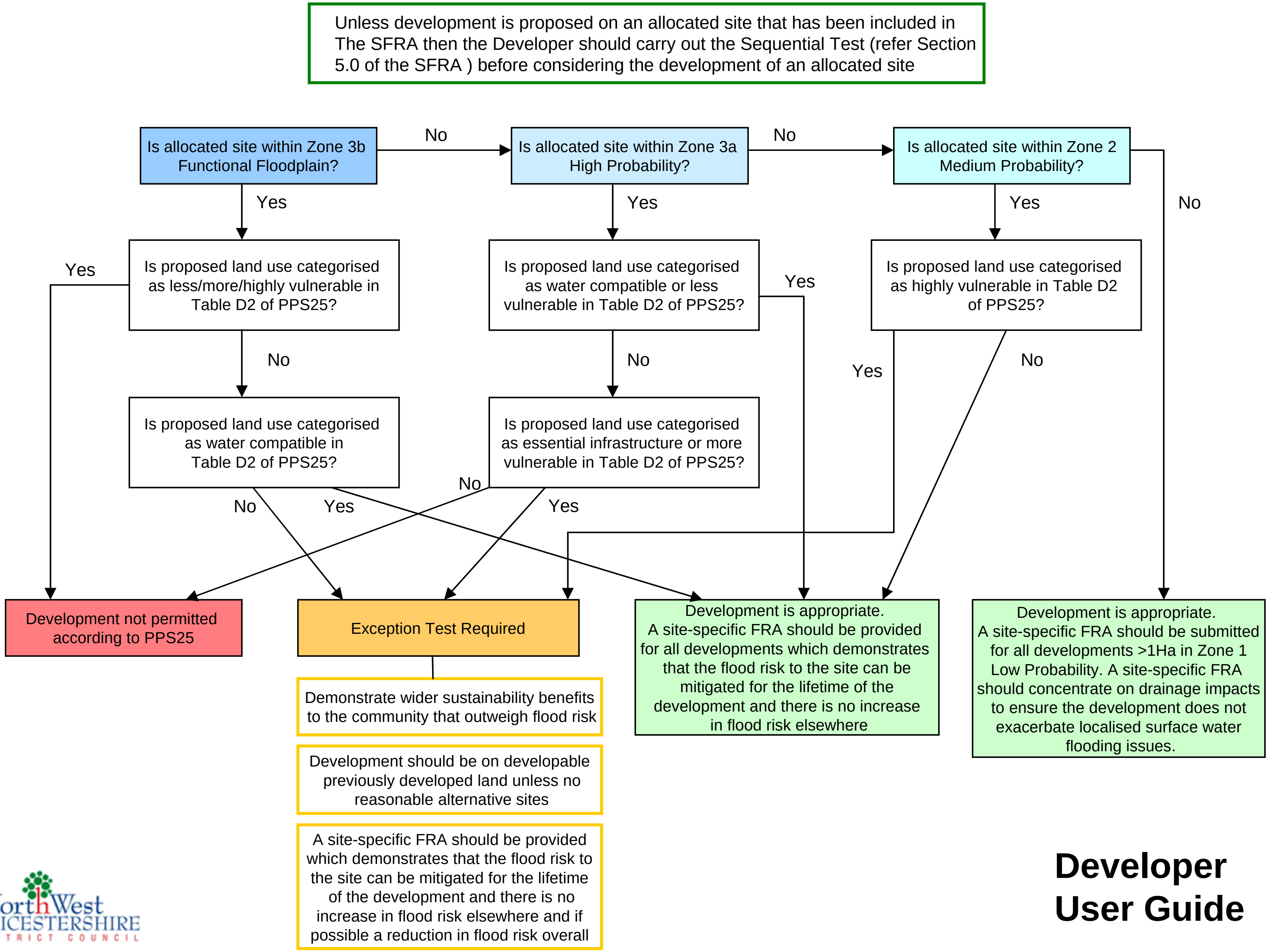
# Appendix C SFRA User Guides




# NWLDC Planning User Guide

North West Leicestershire District Council




NorthWest Leicestershire District Council

# Developer User Guide

## Appendix D    Packington Feasibility Study Technical Report

# D1.0 Introduction

## D1.1 Background

Residents of Packington village have been concerned for several years about the risk of flooding from Gilwiskaw Brook as it flows through the village. Historically the flooding in the village has been during the winter season; however Packington has experienced summer flash flooding in July 2001 and June 2007. The July 2001 event caused flooding to one property; the back gardens of 5 properties and extensive flooding of Mill Street (see Plate D1). Following on from this event, local residents contacted the Environment Agency to investigate potential flood mitigation options and a local resident group FLOAT (Packington Flood Action Group) was set up.

***Plate D1 - Flooding on Mill Street in July 2001 (Source : FLOAT)***

Anecdotal evidence from residents suggests that occurrence of flooding may have become more frequent in the last 10 years or more but there are no historical records available to confirm this. Their concern is that development within Ashby-de-la-Zouch is increasing surface water runoff entering Gilwiskaw Brook and exacerbating flooding within Packington.

A feasibility study has been undertaken as part of the North West Leicestershire SFRA to identify suitable flood storage options which provide attenuation from increased urban development whilst providing some flooding protection to Packington village.

## D1.2 Previous Work

Following on from the flooding in July 2001, the Environment Agency carried out an assessment of the flood risk to Packington and produced a pre-feasibility report[1]. The pre-feasibility study identified an offline upstream flood storage facility located upstream of the village as a possible option to alleviate flooding in Packington. However, standard cost-benefit analysis showed that there were insufficient benefits of the proposed flood alleviation scheme in comparison to the costs of the scheme due to there only being a small number of properties at risk of flooding.

The key recommendations from the Environment Agency study are that residents should consider self protection measures, e.g. flood barriers, for their properties to minimise the impact and damage from future flooding. Riparian owners were also recommended to ensure Gilwiskaw Brook is adequately maintained in the vicinity of their property. Additionally, the Environment Agency report recommended that more

[1] Packington Flood Alleviation Proposals, Environment Agency, November 2001, Pre-feasibility Report – An evaluation of the current land drainage problem(s) including consideration for possible solutions to limit future risk.

detailed hydrological and hydraulic investigations are undertaken to assess the risk to Packington for a range of return periods.

A further feasibility study was carried on behalf of Packington Parish Council which included further hydrological and hydraulic modelling combined with a feasibility study for an offline storage scheme.

## D1.3 Data Collection

The following data has been collected for this study:

Hydraulic Models

- Gilwiskaw Brook S105 model from the Environment Agency
- Packington Parish Council model from JBA Consulting
- Ashby de la Zouch Flood Risk Assessment model from JBA Consulting

Calibration/Verification Data

- Packington river level gauge data from the Environment Agency
- Overseal tipping bucket raingauge data from the Environment Agency
- Flooding photographs from FLOAT

LiDAR[2] data from the Environment Agency

# D2.0 Hydrological Analysis

## D2.1 Introduction

A hydrological analysis has been carried out for the Packington feasibility study to provide design hydrological inflows for the new hydraulic model. The hydraulic modelling has been used to assess storage options and it is, therefore, essential that all the hydrological inflows are represented by a full flood hydrograph. The hydrological assessment has been undertaken using the methods outlined in the Flood Estimation Handbook (FEH) and consisted of the following tasks:

- Review of flood event data for Packington
- Delineation of hydrological inflows to the hydraulic model and derivation of rainfall runoff hydrographs for each inflow
- Verification of the hydrological inflows and hydraulic model by comparison with recorded flood levels at Packington
- Calculation of design flows for the hydraulic model using FEH statistical and rainfall runoff methods

## D2.2 Catchment Description

Figure D1 shows the catchment of Gilwiskaw Brook to Packington. Gilwiskaw catchment is 18.59 $km^2$ to the downstream limit of this study, downstream of Packington village at Stonehouse Farm. Gilwiskaw Brook rises in Smisby and flows through agricultural land before flowing through Ashby. Gilwiskaw Brook is joined by an unnamed tributary to the east of Ashby just north of the A42 crossing.

[2] LiDAR (light detection and ranging) systems work by sending a laser pulse from the carrier aircraft to the ground and measuring the speed and intensity of the return signal.

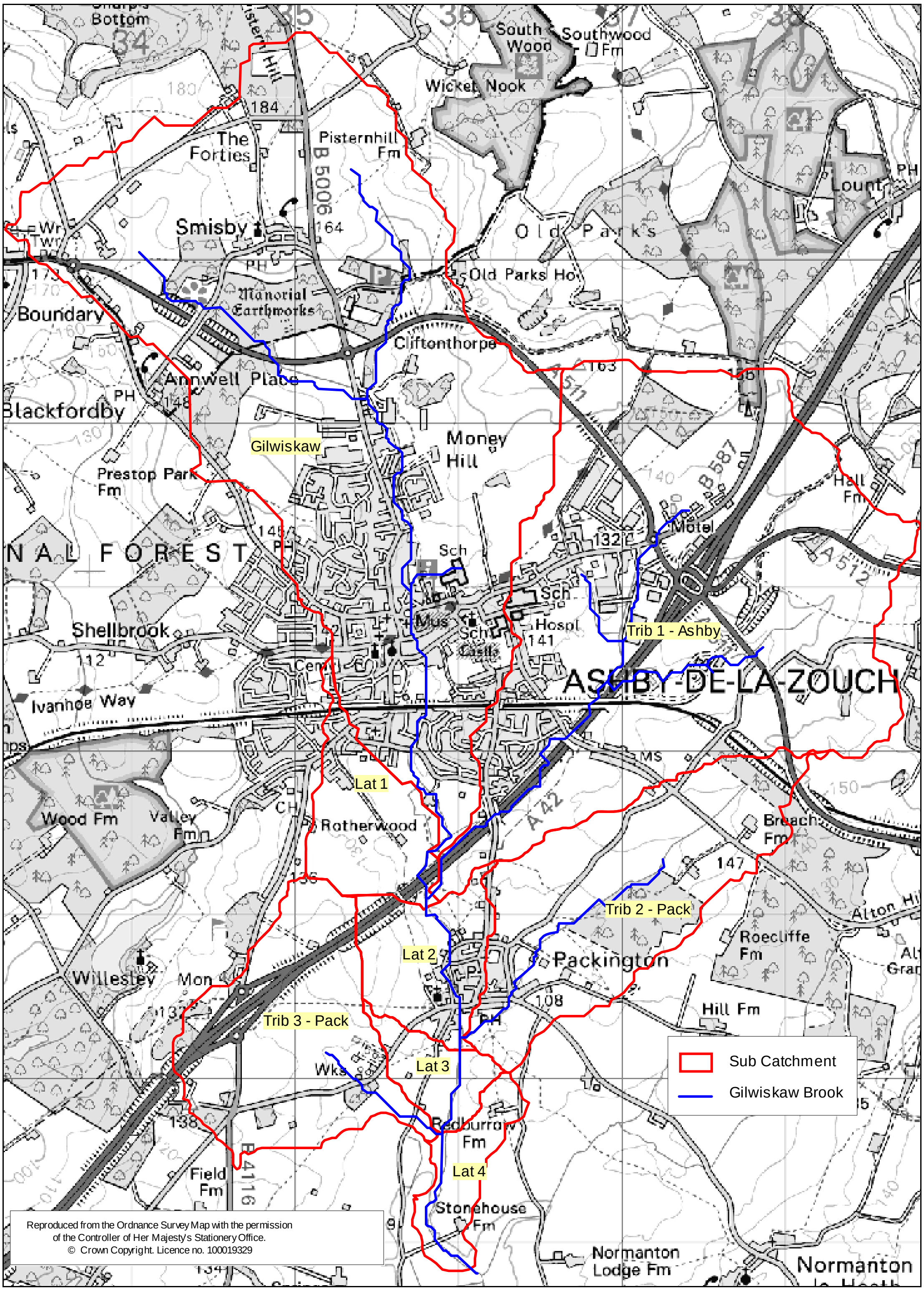



***Figure D1 – Gilwiskaw Catchment***

The catchment is largely rural except for Ashby and Packington and the major road networks, e.g. A42. Urbanisation and improvements in urban drainage in Ashby in recent years have resulted in the efficient collection of surface water runoff and discharge into the culverted parts of Gilwiskaw Brook through Ashby.

The Gilwiskaw Brook catchment was divided into a number of subcatchments as shown in Figure D1 and Table D1. Catchment descriptors were derived from the FEH CD ROM and are listed in the FEH calculation record in Appendix E. Rainfall runoff models have been derived for each of the inflows and have been included in the ISIS model as FEH boundary units (FEHBDY).

Additional FEH catchments were derived at the A42 road crossing and for the downstream limit of the model. The rainfall runoff models for these locations were used to assess catchment rainfall parameters and to derive design flows. FEH statistical flow estimates have been derived for these two locations for comparison.

***Table D1- Gilwiskaw Brook Subcatchments***

| Name | Location | Area ($km^2$) | % of total catchment |
|---|---|---|---|
| **Model Inflows** | | | |
| Gilwiskaw | Gilwiskaw Brook – upstream model extent | 7.56 | 41% |
| Trib1_Ashby | Tributary inflow, joins main river upstream of A42 | 5.58 | 30% |
| Lateral 1 | Lateral inflow area upstream of A42, including field drains to the right of main watercourse | 0.65 | 4% |
| Lateral 2 | Lateral inflow area from A42 to confluence with trib 2 just downstream of Packington | 0.64 | 3% |
| Trib2_Pack | Tributary inflow, joins watercourse just downstream of Packington | 1.92 | 10% |
| Lateral 3 | Lateral inflow area from confluence with tributary 2 to confluence with tributary 3 | 0.30 | 2% |
| Trib3_Pack | Tributary inflow, joins watercourse 1km downstream of Packington | 1.52 | 8% |
| Lateral 4 | Lateral inflow area from confluence with tributary 3 to downstream limit of hydraulic model | 0.36 | 2% |
| **Additional Hydrological Assessment Locations** | | | |
| US_A42 | Entire catchment to the A42 road crossing | 13.87 | 75% |
| Ds_Pack | Entire catchment to downstream limit of model | 18.59 | 100% |

## D2.3 Hydrometric Data

The hydrometric data for the Gilwiskaw Brook catchment has been obtained from the Environment Agency. On Gilwiskaw Brook there is a single river gauge located downstream of Bridge Street in Packington. The gauge is a level only gauge, installed during July 2001. There are no raingauges within the catchment, the nearest raingauge is Overseal, located 6 km to the west of Packington. Overseal is a tipping bucket raingauge, with 15 minute data available since 1974. The gauges are shown in Figure D2 and have been used to verify the hydraulic model (see section D4.0).

Three events were selected for model verification;

- July 2001 (peak level 106.0mAOD)
- October 2004 (peak level 105.3mAOD)
- June 2007 (peak level 105.9mAOD)

15 minute level data at Packington and rainfall data at Overseal is available for each of these events. July 2001 and June 2007 are the two largest events on the Packington record.

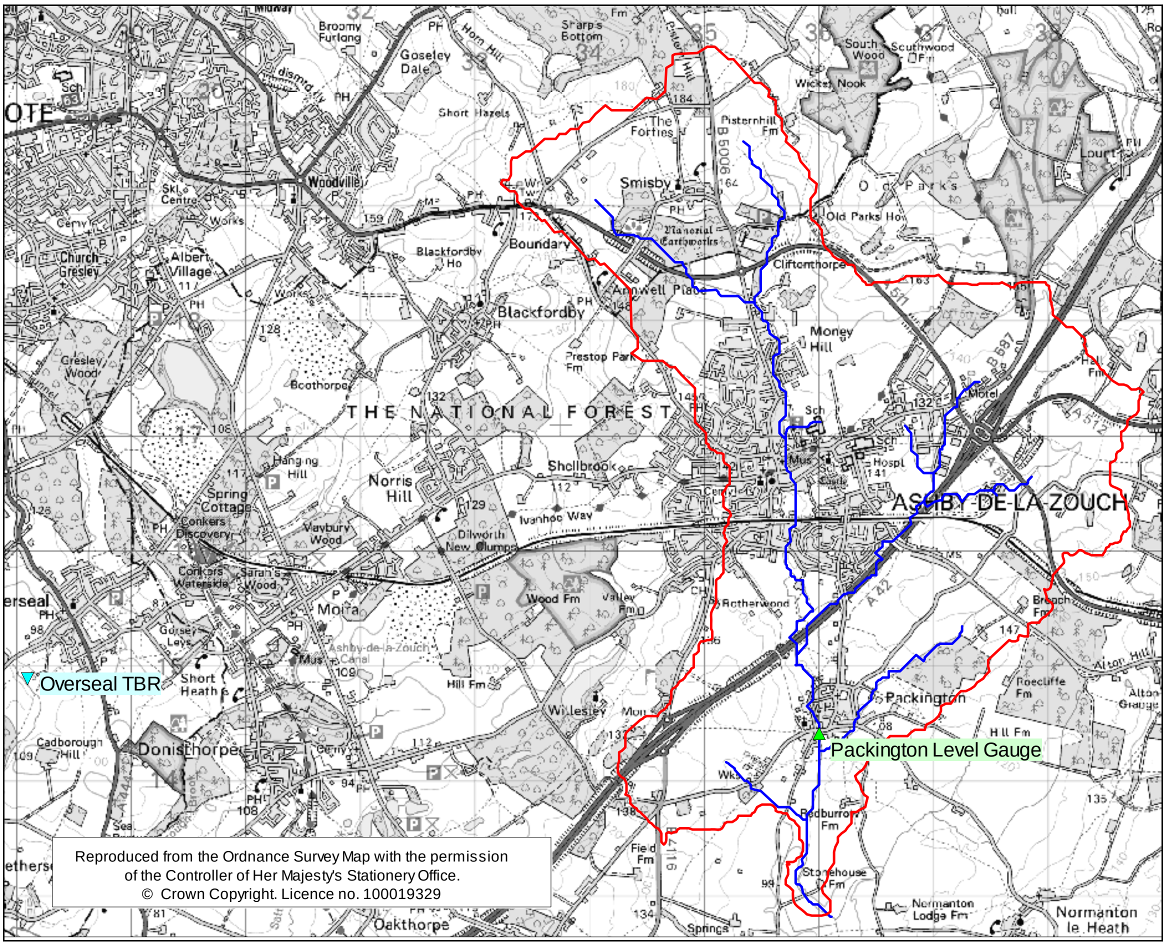



*Figure D2 – Hydrometric Data*

## D2.4 FEH Statistical Method

A number of approaches were identified for use in the study – namely the standard FEH Statistical and Rainfall-Runoff techniques.

Statistical estimates have been generated for two points of interest; the catchment upstream of the A42 and the whole catchment to downstream of Packington.

### QMED Estimation

Pooling groups were derived using sites indicated by HiFlows-UK as suitable for QMED in order to identify sites that are hydrologically similar to the subject site, however greater emphasis was placed on the geographical location of donor sites. A number of sites in the Midlands were identified as potential donor sites using the FEH record. Most of the selected sites were giving similar ratios between QMED from catchment descriptors and QMED from AMAX. The adjustment ratios derived from AMAX and CD estimates of QMED at the two points of interest are shown in Table D2.

*Table D2 - QMED Estimates for Points of Interest*

| Name | Initial estimate of QMED ($m^3/s$) | Donor sites used | Final estimate of QMED ($m^3/s$) |
|---|---|---|---|
| u/s A42 | 2.26 | Dowles, Witham & Chater | 3.37 |
| d/s Packington | 2.79 | Dowles, Witham & Chater | 4.15 |

**Pooling Groups**

A target return period of 120 years was used to create a pooling group containing 600 years worth of data, so that after review and rejection of sites within the group some 500 years would still remain. 500 years of data is critical because it represents 5T, where T is the significant design event to be analysed. In this study, the 100 year return period is considered to be the critical flood. The pooling group will also be used to calculate growth curves for all return periods.

WINFAP automatically selects hydrologically similar catchments from the HiFlows-UK sites that are defined as being suitable for pooling. The growth curves of these gauged locations are then combined to create a composite growth curve for the study site, allowing predictions of peak flow for return periods of interest to be generated.

**Statistical Method Peak Flow Estimates**

***Table*** D3 shows the statistical estimates of peak flows generated for each return period. Note the values given in italics are beyond the range of applicability for the method and are included only for comparative purposes.

***Table D3 - Peak flows estimated using the FEH statistical method***

| Name | Flood peak ($m^3/s$) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | |
|---|---|---|---|---|---|
| | 50% (2) | 5% (20) | 1% (100) | 0.5% (200) | 0.1% (1000) |
| u/s A42 | 3.37 | 7.1 | 9.3 | 10.2 | *12.3* |
| d/s Packington | 4.15 | 8.8 | 11.7 | 12.9 | *15.6* |

## D2.5 Rainfall-Runoff Method

The rainfall-runoff method has been used to generate flow hydrographs for input to the ISIS model, rather than just the peak flow values that the statistical method generates. ISIS FEH boundary units (FEHBDY) were generated for each sub-catchment and lateral inflow within Table D1 to create a rainfall runoff model to each point.

Upon completion of the hydraulic model, flow hydrographs for each sub-catchment and lateral will be routed through the hydraulic model to provide rainfall runoff flow estimates throughout the modelled reaches.

The RR method estimates flows by examining the relationship between rainfall and hydrological response of a catchment to a storm event. Three key parameters are used by the RR model to define the hydrological characteristics of a catchment. These are:

- Catchment response time to rainfall (Unit Hydrograph time-to-peak, Tp)
- Proportion of rainfall which directly contributes to river flow (percentage runoff, PR)
- Quantity of flow in the river prior to the storm event (baseflow, BF)

Rainfall is defined in terms of duration, depth and distribution (over time) and may relate to either a probabilistic design event, e.g. 1 in 100 year return period, or an observed storm event (for calibration purposes).

A series of hydrographs have been produced for each of the tributaries and lateral inflows, which form the inputs to the hydraulic model of Gilwiskaw Brook. These inflows will be routed through the hydraulic model to provide RR estimates at any location within the model reach.

As the inflows are routed through the hydraulic model, significant attenuation of the hydrographs can occur, and the resulting flows in the river channel are therefore a function of both the hydrological and hydraulic characteristics of the river system.

The initial inflows for each sub-catchment used for the development of the hydraulic model are summarised in Table D4.

***Table D4 – Previous Model Details and Extents***

| Name | Design Storm Duration (hours) | Flood peak ($m^3/s$) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | |
|---|---|---|---|---|---|---|
| | | 50% (2) | 5% (20) | 1% (100) | 0.5% (200) | 0.1% (1000) |
| Gilwiskaw | 9.25 | 2.1 | 4.8 | 7.4 | 8.8 | 13.6 |
| Trib 1_Ashby | 9.25 | 1.2 | 2.8 | 4.3 | 5.1 | 7.9 |
| Trib 2_Pack | 9.25 | 0.6 | 1.3 | 2.0 | 2.4 | 3.7 |
| Trib 3_Pack | 9.25 | 0.4 | 1.0 | 1.5 | 1.8 | 2.7 |
| Lat 1 | 9.25 | 0.4 | 0.6 | 0.9 | 1.1 | 1.6 |
| Lat 2 | 9.25 | 0.2 | 0.6 | 0.9 | 1.0 | 1.6 |
| Lat 3 | 9.25 | 0.1 | 0.2 | 0.4 | 0.4 | 0.7 |
| Lat 4 | 9.25 | 0.1 | 0.3 | 0.4 | 0.5 | 0.8 |
| Gilwiskaw _u/s_A42 | 9.25 | 3.5 | 7.7 | 11.6 | 13.8 | 21.2 |
| Gilwiskaw _d/s_Pack | 9.25 | 4.5 | 10.1 | 14.6 | 18.7 | 27.6 |

# D3.0 Hydraulic Analysis

## D3.1 Introduction

Three models from previous studies were available to combine in order to produce the final hydraulic model for this study. These models covered differing extents of Gilwiskaw Brook as summarised in Table D5 and as discussed below.

***Table D5 – Previous Model Details and Extents***

| Model Name | Extents | No of Nodes | Model Length (km) | No of structures | D/S Bdy | U/S Bdy |
|---|---|---|---|---|---|---|
| JBA Packington | Packington Village | 33 | 0.9 | 5 | Head Time | Flow Time |
| JBA Ashby de la Zouch | South Ashby de la Zouch to A42 | 82 | 1.1 | 1 | Head Time | FEH & Flow Time |
| BBV Gilwiskaw | South Ashby de la Zouch to confluence with River Mease | 187 | 8.3 | 16 | Head Time | Flow Time |

**Packington Parish Council Model**

The first model available covers the reach through the village of Packington, from the A42 road bridge upstream to the road bridge at Bridge Street at the south end of the village. The model originates from a JBA study conducted for the Packington Parish Council investigating the potential for an offline flood storage area to alleviate periodic flooding of the village.

The average section spacing in this model is between 60 and 90 metres, with some shorter spaces where structures dictate them. The average channel width for this reach is around 5m. The gradient of the reach is approximately 1 in 270m.

The reach covered is around 0.9km, passing through the village of Packington, and contains 5 structures. The first of these structures is the small footbridge upstream of the Mill. This was modelled as a General Head Loss in ISIS, with a loss coefficient of 0.5. The four remaining structures, representing bridges at Mill Street, Hall Lane, Little Lane and Bridge Street, are all modelled with Arch Bridge units, and all four of these structures include a spill. The spills in each case are modelled as spills over bank from a distance of around 5m upstream to the bridge itself, rather than as a spill over the bridge deck, with any flow over these spills returning to the channel immediately downstream of the structure concerned.

There is a single inflow to the model at the upstream end, and this is represented by a Flow-Time boundary unit, while the downstream boundary is represented by a Head-Time boundary unit.

The model runs with the initial conditions set in the DAT file.

Details of the hydraulic model can be found in the 'Feasibility for Flood Storage Area at Packington' Report (JBA – 2003).

**JBA Ashby de la Zouch Model**

The second of the models covers a reach upstream of the first model, from the point where the Lower Packington Road bridge crosses Gilwiskaw Brook at the upstream end, to the A42 at the downstream end. The model includes an unnamed tributary and a drainage ditch connected at its upstream end to the main channel via overland flow. This model also originates from a JBA study from September 2007, conducted for Hallam Land Management to investigate the feasibility of a proposed flood storage area to alleviate flooding in Packington.

The average section spacing in the main reach of this model is 15 – 25 metres in the top half of the reach and 50 – 70 metres in the bottom half of the reach. The average gradient over the main reach of the model is approximately 1 in 120m, making it much steeper than the Packington Parish Council Model downstream. The average spacing of sections on the unnamed tributary is 45 – 70 metres and the gradient is approximately 1 in 100m. The average spacing of sections on the overland sections and drainage ditch is 35 – 60 metres and the gradient is very steep at approximately 1 in 77m.

The reach of Gilwiskaw Brook covered is approximately 1km in length, and passes through rural land to the immediate south of Ashby de la Zouch. There is only one structure modelled on this reach, this being the culvert under Mill Farm. This is modelled with conduit sections and a spill over the top. This culvert has been modelled as being in a different location and a different length to the actual culvert as it follows the path of a proposed diversion channel round the side of Mill Farm.

The unnamed tributary in the model is approximately 340 metres in length and no structures are modelled. The drainage ditch, which passes along the opposite side of Mill Farm to the main channel and culvert, is around 0.5km long, and also has no structures modelled.

There are three inflows to the model. Two of these, at the upstream ends of the Gilwiskaw Brook reach and the unnamed tributary, are represented by FEH Boundary units. The final inflow is a Flow-Time boundary unit at the upstream end of the drainage ditch and overland units, and this represents a minimum flow through this reach to allow the model to run. The downstream boundary is represented by a Head-Time boundary unit.

The model runs with the initial conditions set in the DAT file.

Details of the hydraulic model can be found in the 'Ashby de la Zouch Flood Assessment' Draft Report (JBA – 2007).

**Environment Agency Gilwiskaw Brook S105 Model**

The third model covers a much larger reach of Gilwiskaw Brook than the first two models. The upstream end of the model is located at a point just upstream of Lower Packington Road in south Ashby de la Zouch, around the same point as the upstream end of the JBA Ashby de la Zouch model (section 0). The downstream end of the model is at the downstream end of Gilwiskaw Brook at its confluence with the River Mease. This is around 6km further downstream than the downstream end of the JBA Packington Model (section 0). This model includes the same unnamed tributary as the JBA Ashby de la Zouch model (section 0), covering approximately 0.4km of it. This model originates from a BBV study.

The average section spacing along the main reach of this model varies greatly from 15 metres in some places to 200 metres in others. The average gradient over the entire main reach of this model is approximately 1 in 220m.

The average is spacing along the unnamed tributary is around 30 metres at the upstream end and around 100 metres at the downstream end. The average gradient of this reach is approximately 1 in 85m.

The model contains 16 structures in total, 13 being bridges, and 3 culverts. All of the bridges are modelled as arch bridges, the majority without spill sections over the bridge. However, three of the bridge units utilise weir units as spills for flow overtopping bridges, these being the bridges at Hall Lane, Mill Street and Little Lane in the Village of Packington. Two of the bridges without spills are located on the unnamed tributary while the rest are spread along the main reach in the model. The first of the culverts is located at Mill Farm and is modelled as a culvert inlet and culvert outlet with conduit sections and a culvert bend between. This is modelled differently from the culvert in the JBA Ashby de la Zouch model as it follows the original path of the watercourse rather than the proposed diversion channel path. The two other culverts are at the downstream end of the model. This first of these passes under a track and is modelled as a pair of culverts inlets and outlets with conduit sections between each. The final culvert is under the B4116 Measham Road. Again, this is modelled as a culvert inlet, a culvert outlet and conduit sections in between.

There are ten inflows to this model, all of which are represented by Flow-Time Boundary units. These inflows represent the upstream inflows at the top of Gilwiskaw Brook and the unnamed tributary, as well as inflows from subcatchments along the reach. The downstream boundary is represented by a Head-Time boundary unit.

The model runs with the initial conditions set in the DAT file, but it requires a low time step.

## D3.2 Adaptation of Existing Models

### D3.2.1 Model Extents

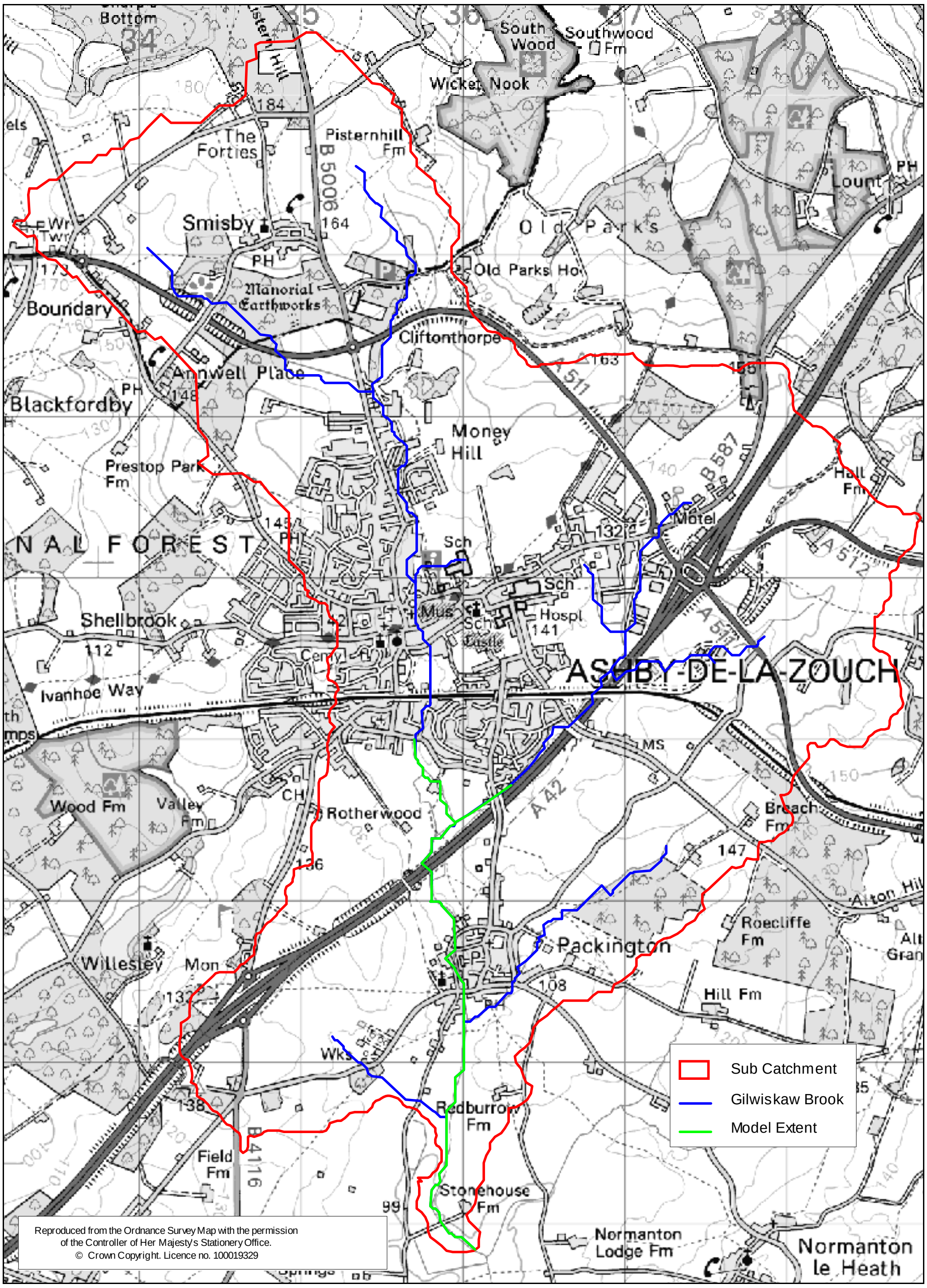



***Figure D3 – Gilwiskaw Hydraulic Model Extent***

Various parts of each of the three existing models were combined to produce the final hydraulic model of Gilwiskaw Brook. The entire reaches of the two JBA models were used, and the upstream boundary from the JBA Ashby de la Zouch model was taken as the final upstream boundary. These two models were joined at the point where Gilwiskaw Brook passes under the A42 road bridge upstream of Packington. A section of the Environment Agency S105 model was then used to extend the downstream boundary of the model by over 3km further downstream than the

Packington Parish Council model allowed. This helps to mitigate the effects of the downstream boundary on the area around Packington. It was decided to cut off the S105 model from the point of Measham Hall and the Clock Mill downwards, reducing the overall length of the model by a little over 3km.

The total length of the 'new' model after joining the three pieces together is 5.1km, as well as the unnamed tributary, which is 360m and the drainage ditch which is 533m. Figure D3 shows the model extent.

### D3.2.2 Model Chainages

Chainages in the three original models had to be checked and were found in places to differ from mapping tables showing section locations. In the S105 model the chainage of each section was identified by the reference given to it, for example GW7896 referred to a section at a chainage of 7896 metres from the downstream boundary, and this was backed up by a mapping table of nodes for this model. However, when the model chainages for each individual node were added together it was found that this section had a model chainage of 7589 metres.

The JBA Packington model chainages matched up with those given in mapping tables. However, the JBA Ashby de la Zouch model chainages again differed from the mapping tables provided with the total chainage in the model totalling around 50 metres more than that when measured using GIS software. When the chainages were examined it was found that the area around Mill Farm, where the proposed diversion channel is sited, had too much chainage. The downstream area of the model, around the A42, was also found to have too much chainage.

The chainages in the models were altered to match up with those measured in the GIS software, either by changing the chainages between each node, or in some cases deleting sections.

### D3.2.3 Model Boundaries

New hydrological inflows were created for the model at the upstream ends of Gilwiskaw Brook, the unnamed tributary and the drainage ditch, as well as from the subcatchments along the model reach. These inflows were all represented by FEH boundary units. The downstream boundary was created at the point at which the S105 model was cut off. A Normal Depth Boundary was used to represent the downstream boundary and the slope was calculated using the final few sections of the model.

### D3.2.4 Structures

Ten structures were included in the final model, two of which are bridges on the unnamed tributary, a further seven bridges on the main Gilwiskaw Brook reach, and one culvert on the main reach. All of the bridges are modelled as arch bridges except for one, which is modelled as a general head loss.

The two bridges modelled on the unnamed tributary represent those where Ashby Road and the track adjacent to it cross the watercourse. Both are modelled as arch bridges, with the structure details for each being taken from the S105 model, while the section details were taken from the JBA Ashby de la Zouch model which had a greater amount of detail in the sections than the BBV model.

The first structure on the Gilwiskaw Brook reach is the culvert at Mill Farm. The proposed diversion channel with the culvert under the track was used in the model, as in the JBA Ashby de la Zouch model and therefore the culvert was also taken from this model. The culvert was modelled as conduit sections with a spill over the top.

The next structure on the Gilwiskaw Brook reach is the bridge where the A42 crosses the watercourse. The structure details for this bridge were taken from the BBV model, and the cross section details were taken from the JBA Ashby de la Zouch model.
The next structure on the main reach is the small footbridge modelled as a general head loss. This is located just upstream of the Mill. The structure was taken from the Packington Parish Council model.

The next four bridges are those through Packington and are taken from the Packington Parish Council model. They represent the structures at Mill Street, Hall Lane, Little Lane and Bridge Street. The first three of these structures also has a spill attached for overtopping of the bridge. The spills are modelled such that they represent a section of bank from the bridge unit to a point upstream which will allow flow to rejoin the channel immediately downstream of the bridge unit if they are overtopped.

There is one further bridge downstream which represents the bridge for the track at Stonehouse Farm. The structure and cross section details for this bridge were taken from the S105 model.

### D3.2.5 Model Stability

Interpolates and spill sections were used throughout the model to improve the stability. While there were no interpolated sections in the JBA Packington model, both of the other models contained interpolated sections already and these were incorporated into the model, along with further interpolates where necessary.

The interpolates from the existing models were altered such that the spacing between them and the sections either side was even as it was found to improve the stability of the model.

Spills were used to improve model stability where a large change in the bed slope caused instabilities to occur. This happened in two places at DRAIN_0473 on the drainage ditch, and GILW01_4735 on Gilwiskaw Brook. These spills were given a weir coefficient of 3, as the spills do not actually exist in the channel and this weir coefficient minimises any head loss caused by the modelled spill. The spill allows the water surface slope to be changed to a greater degree at a single point than when sections alone are used, thus overcoming instabilities. Spills were also used to overcome stabilities at the confluences of the unnamed tributary and the drainage ditch with Gilwiskaw Brook.

## D4.0 Model Verification

Verification of the model was undertaken for three events; July 2001, October 2004 and June 2007. The verification process, undertaken for each event, is as follows:

- Data from the Overseal raingauge was used to provide an event rain profile
- The catchment wetness index (CWI) and event percentage runoff (PR) was calculated for each subcatchment inflow
- The rain profiles, CWI and PR were used within the FEH boundary units to generate event flow hydrographs
- Flow hydrographs were routed through the hydraulic model and the modelled levels at Packington compared with the recorded levels

The verification hydrographs are shown in Figure D4. For all events it can be seen that the modelled levels are too high at low flow conditions. This is due to minimum flows which are used in the hydraulic model to counter instabilities at low flow: minimum flows are applied so that the low flow values are increased but the peak flows are unchanged.

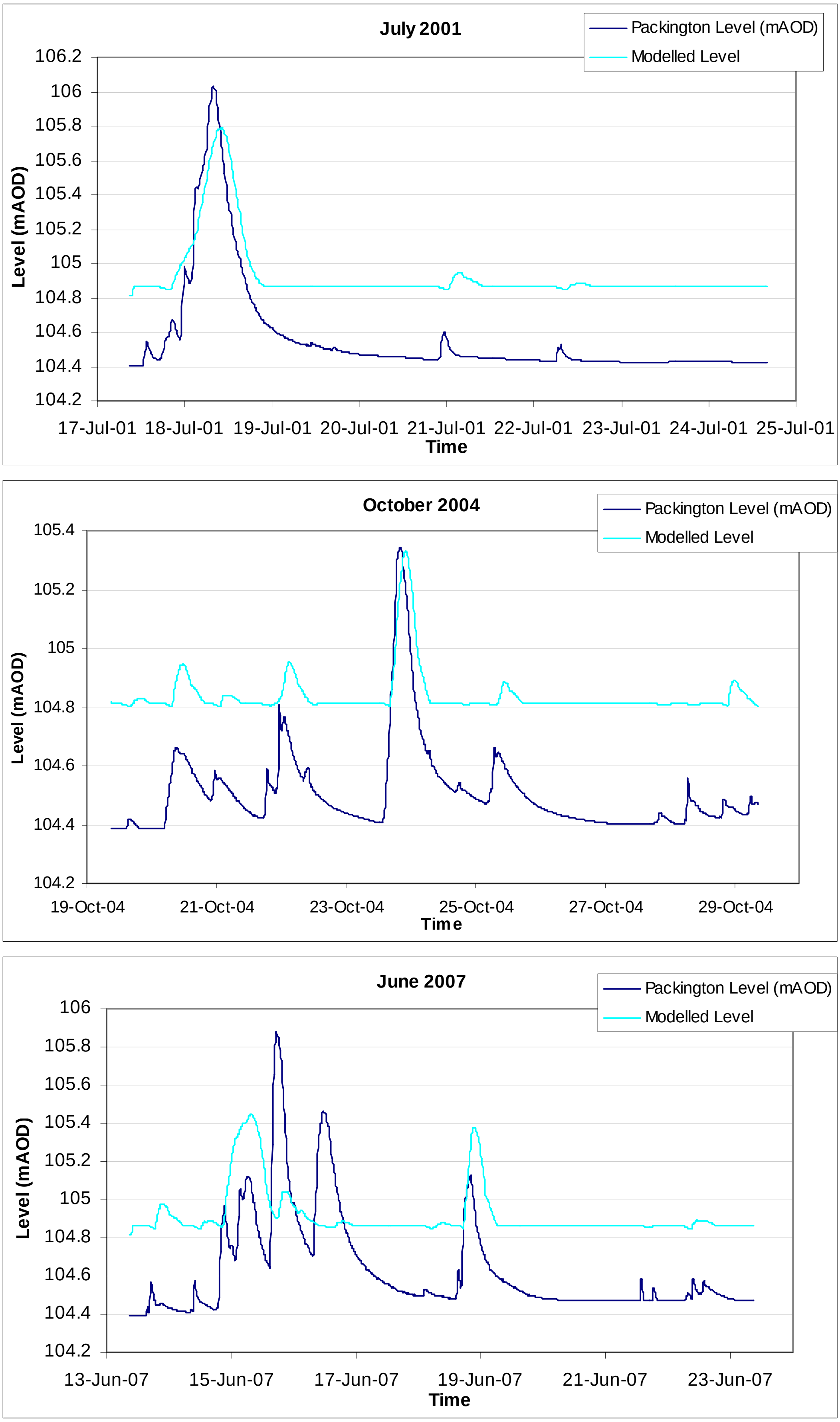



***Figure D4 – Verification of Hydraulic model***

For two events July 2001 and October 2004 the shape and timing of the hydrographs is very good; however for June 2007 the hydrograph shape varies significantly suggesting that the rain profile for this event may not be representative as Ashby and Packington experienced a flashy event from a summer thunderstorm

The peak levels at Packington are a very good fit for October 2004, within 20mm but 360mm lower on the July 2001 event.

Without a flow gauge on the river it is not possible to fully calibrate the model and any variations in modelled levels could be due to a number of hydrological and hydraulic factors that cannot be explicitly identified. For the purposes of this study the verification has shown the rainfall runoff model does produce the observed catchment response and the modelled levels are within reasonably close agreement to the gauged levels at Packington.

# D5.0 Design Flow Analysis

Design flows were estimated for Packington using FEH statistical and rainfall runoff methods for the 20, 100, 200 and 1000 year events. To allow for the effects of climate change a 20 % increase in the 100 year flow has also been considered.

The verified rainfall runoff model was used to calculated design rainfall runoff flows; a catchment wide storm of duration 9.25 hours was applied to each model inflow and routed through the hydraulic model. The resultant peak flows at the A42 and downstream of Packington are given in Table D6.

Design peak flows were compared with the FEH Statistical Method estimates which showed that the design peak flows for the rainfall runoff method are higher than the statistical method. The rainfall runoff flows have been used in preference for this study to retain a conservative approach to flood risk.

***Table D6 - Comparison of peak flow estimates***

| Location | Method | QMED | Q20 | Q100 | Q200 | Q1000 | Q100+20% |
|---|---|---|---|---|---|---|---|
| US_A42 | Statistical | 3.37 | 7.1 | 9.3 | 10.2 | | |
| | Rainfall runoff | 3.5 | 7.7 | 11.6 | 13.8 | 21.2 | 13.9 |
| Ds_Pack | Statistical | 4.15 | 8.8 | 11.7 | 12.9 | | |
| | Rainfall runoff | 4.5 | 10.1 | 14.6 | 18.7 | 27.6 | 18.2 |

# D6.0 Flood Risk Areas

The hydraulic models were run for each of the design scenarios to assess the level of flooding within Packington and Ashby. Figure D5 shows the mapped flood outlines for the Q20, Q100, Q1000 and Q100 + 20% increase in flow representing climate change. Table D7 summarises the number of properties at risk within Packington and Ashby for each of the return periods and the approximate depths and velocities of flood water. The modelled stage and flows for each of the return period events and for each of the cross sections within the model are provided in Appendix F.

Figure D5 and Table D7 show that flooding of Mill Street and gardens within Packington occurs for low return periods (< 20 years). Property flooding is more likely for higher return periods with up to 16 properties affected.

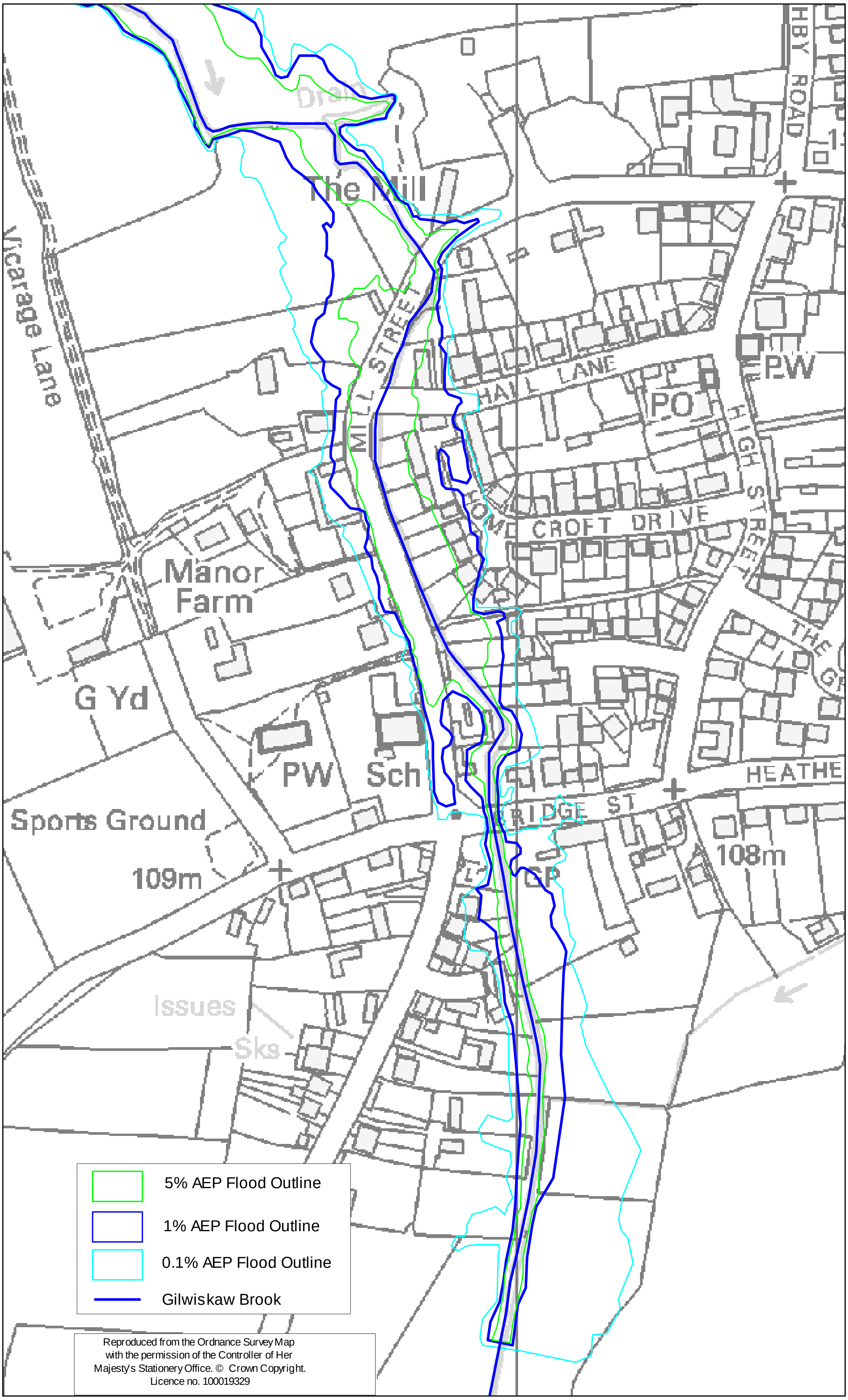



***Figure D5 – Flood Risk in Packington***

***Table D7 – Summary of Flood Risk in Packington for Design Scenarios***

| Risk | Q20 | Q100 | Q100 + CC | Q1000 |
|---|---|---|---|---|
| **No. of properties** | 6 | 16 | 20 | 27 |
| **No. of gardens** | 28 | 30 | 35 | 40 |
| **Roads affected** | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street |
| **Maximum depth of flooding** | 0.6m on Mill Street | 1m on Mill Street | 1.3m on Mill Street | 1.6m on Mill Street |

# D7.0 Flood Storage Options

Potential flood storage was identified upstream of the A42 in the Nook Farm area and downstream of the A42 in the rural area before Gilwiskaw Brook reaches Packington. Several scenarios were tested using the hydraulic model. All scenarios utilised the area identified at Nook Farm as seen in Figure D6 below. To allow for this area, reservoir units were added to the 1% AEP model and an orifice unit was used to restrict flow at the A42. Two different scenarios were tested for differing restrictions on the flow. Further to this, the area between the A42 and Packington was also tested as a potential flood storage area by increasing the channel width in the area, and placing a further restriction on the flow just upstream of the road bridge where Gilwiskaw Brook enters Packington.

The area defined as reservoirs in the Nook Farm area created a potential online storage capacity of 124,800 $m^3$. It was assumed the A42 road embankment would act as a flood embankment.

## D7.1 Storage Upstream of A42

The first scenario tested was with the area defined in Figure D6 as the reservoir storage and a restriction placed on the flow just upstream of the A42. The restriction was modelled using an orifice unit in the ISIS model and the opening of the orifice was given an area of 0.91 $m^2$. This orifice restricted the flow below the A42 to around 6.1 cumecs through Packington. For this 1% AEP scenario a volume of 36,159$m^3$ was stored within the flood storage area. For the Climate Change scenario of 20% increase in flow the volume of flood storage required for this scenario is 39,441$m^3$. Figure D7 shows the comparison between the flood extents for the flood storage area and the 1% AEP.

The second scenario tested for the Nook Farm storage area was with the restriction placed on the flow changed to an area of 0.7 $m^2$ allowing a flow of 5 cumecs below the A42 through Packington. This again resulted in some of the flow backing up behind the A42 and a volume of 38,172$m^3$ was stored within the flood storage area. This scenario results in less flow through Packington and the depth of flooding is reduced by up to 200mm. For the Climate Change scenario of 20% increase in flow the volume of flood storage required for this scenario is 38,220$m^3$. There is only a small change in volume stored for the climate change scenario because flow is attenuated further upstream at structures and within the floodplain upstream of Mill Farm. Figure D8 shows the comparison between the flood extents for the flood storage area and the 1% AEP.

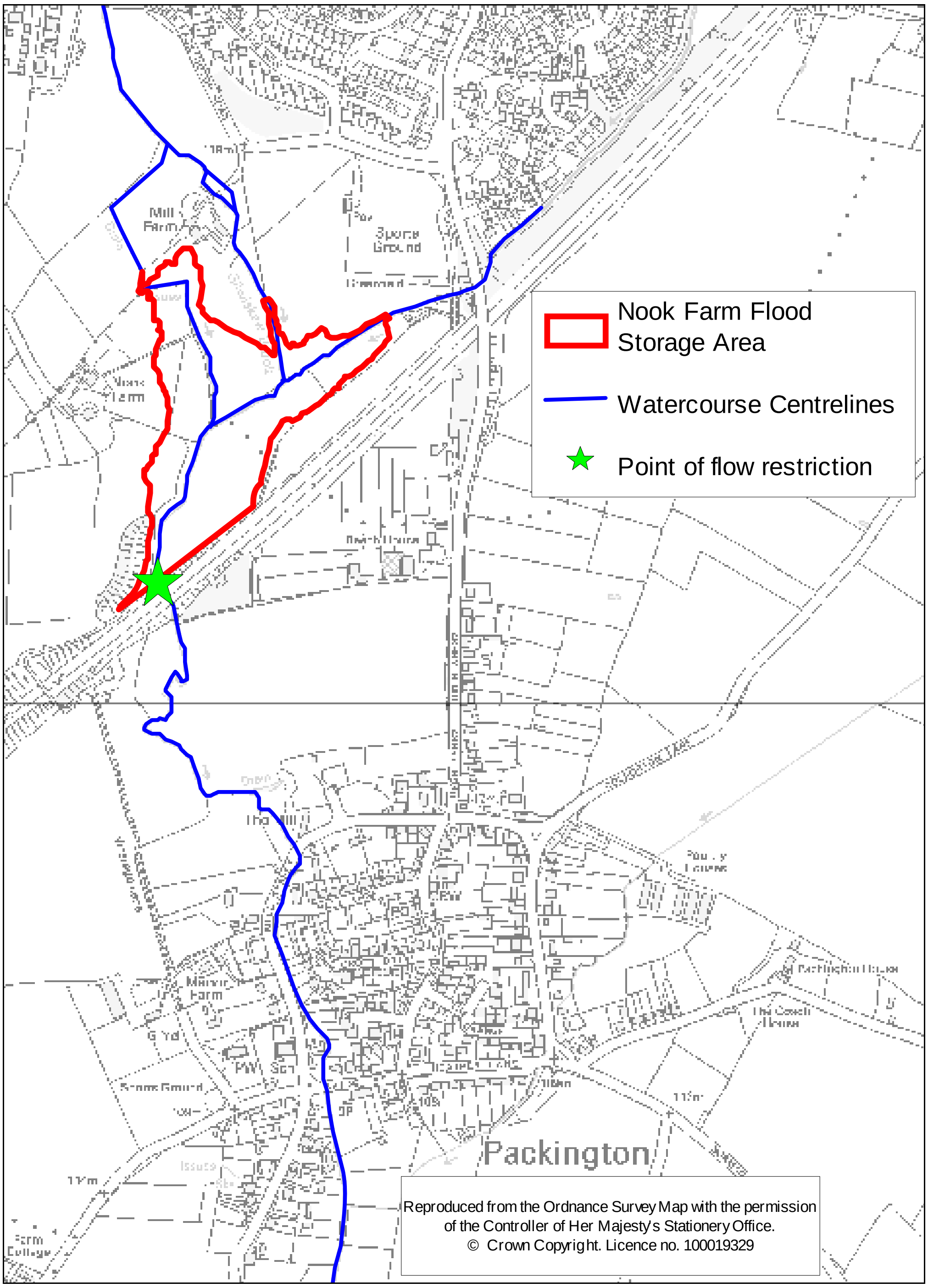



***Figure D6 – Flood Storage Area***

Table D8 provides a summary of the flood risk for the flood storage options. The table shows that the flood storage area provides considerable benefit to flooding in Packington with a reduction in the number of properties and depths of flooding. Although the number of properties, gardens and roads is not significantly reduced for the additional storage that Option 2 provides, there would be significant benefit gained from the reduction in the depth of flooding along Mill Street and to the 2 properties on the corner of Mill Street and Bridge Street.

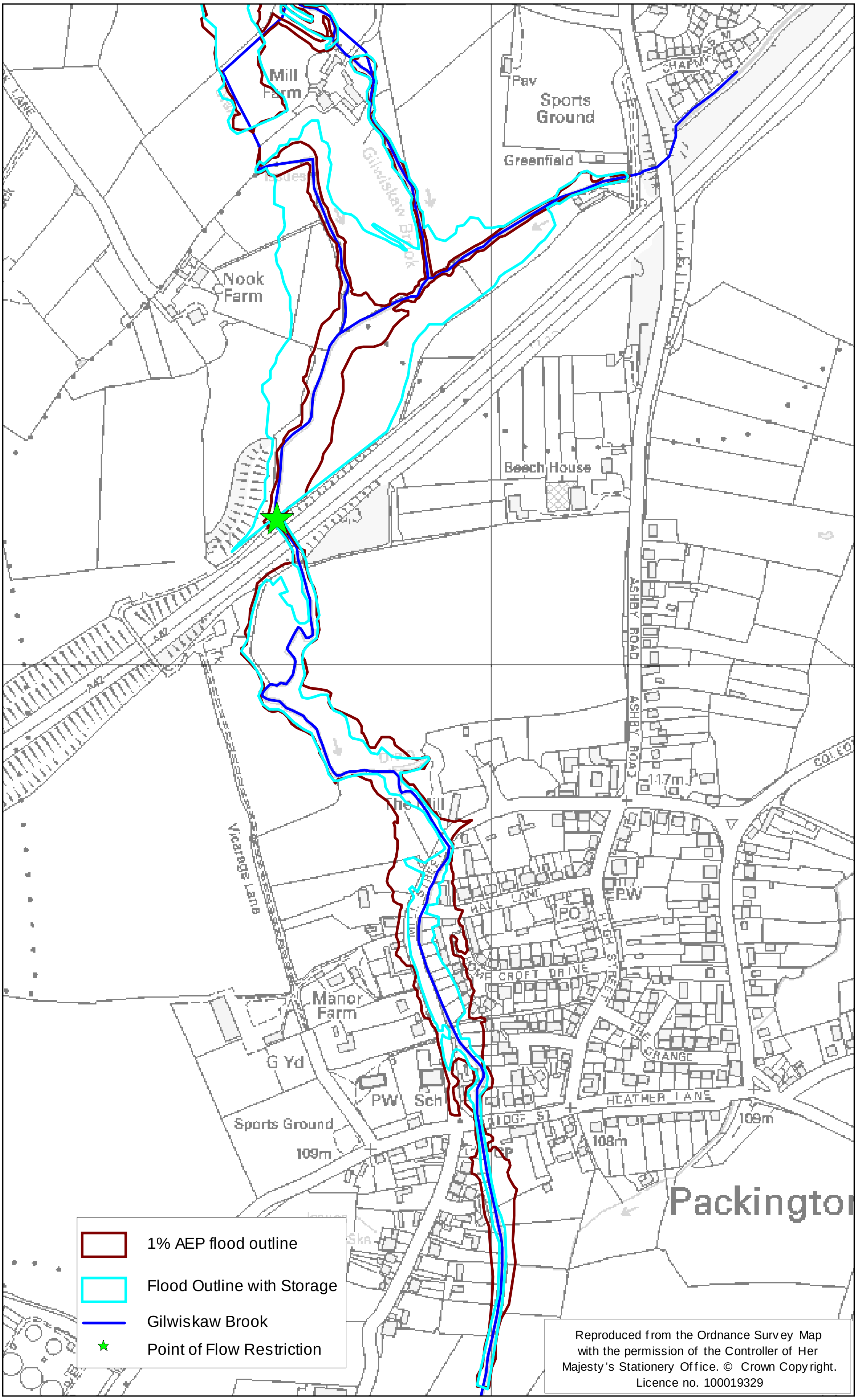



***Figure D7 – Scenario 1 Flood Storage Upstream of A42***

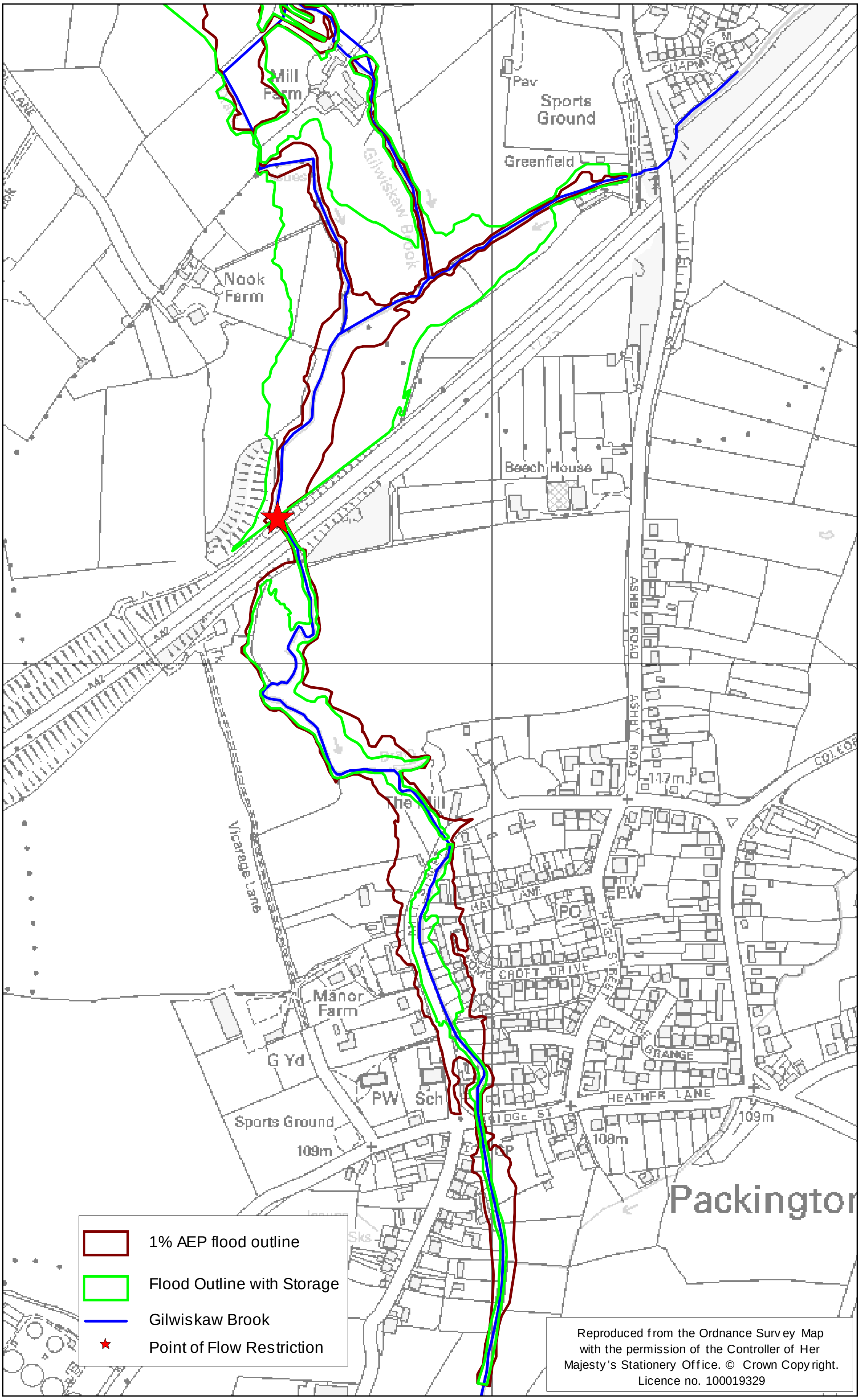



***Figure D8 – Scenario 2 Flood Storage Upstream of A42***

***Table D8 – Summary of Flood Risk in Packington for Flood Storage Options***

| Risk | Q100 | Q100 + CC | Option 1 Q100 | Option 1 Q100 + CC | Option 2 Q100 | Option 2 Q100 + CC |
|---|---|---|---|---|---|---|
| **No. of properties** | 16 | 20 | 3 | 3 | 2 | 2 |
| **No. of gardens** | 30 | 35 | 21 | 21 | 20 | 20 |
| **Roads affected** | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street |
| **Maximum depth of flooding** | 1m on Mill Street | 1.3m on Mill Street | 0.4m on Mill Street | 0.42m on Mill Street | 0.22m on Mill Street | 0.23m on Mill Street |

Table D9 provides a summary of the flood risk in Packington for Storage Option 2 for various return periods and Figure D9 shows the difference in flood storage areas.

***Table D9 – Summary of Flood Risk in Packington for Flood Storage Option 2***

| Risk | Q20 | Q100 | Q1000 |
|---|---|---|---|
| **No. of properties** | 1 | 2 | 2 |
| **No. of gardens** | 20 | 20 | 20 |
| **Roads affected** | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street | Mill Lane, Hall Lane, Bridge Street |
| **Maximum depth of flooding** | 0.15m on Mill Street | 0.22m on Mill Street | 0.25m on Mill Street |

## D7.2 Additional Storage Downstream of A42

Flood storage facilities are classified as impoundments and as such if they exceed 25,000m$^3$ they would come under the jurisdiction of the Reservoir Act 1975. The Reservoir Act requires a rigorous inspection and monitoring regime conducted by a qualified Reservoir Panel Engineer. It is recommended that any proposed flood storage facility is less than 25,000m$^3$ day.

For a flood storage volume of 25,000 m$^3$ the restriction was modelled using an orifice unit in the ISIS model and the opening of the orifice was given an area of 1.7 m$^2$. This orifice restricted the flow below the A42 to around 8.9 cumecs through Packington. However, for this smaller storage volume option there would still be 9 properties at risk of flooding in Packington for the 1% a.e.p with 23 gardens at risk and the maximum depth of flooding being 0.6m on Mill Street.

Additional flood storage could be provided downstream of the A42 with a flow restriction upstream of the Mill Street Road Bridge. The topography in this area upstream of Packington does not provide as large a potential flood storage area as that upstream of the A42. However, there is sufficient area to provide the additional storage that is required over and above the 25,000 m$^3$ to reduce the properties at risk within Packington.

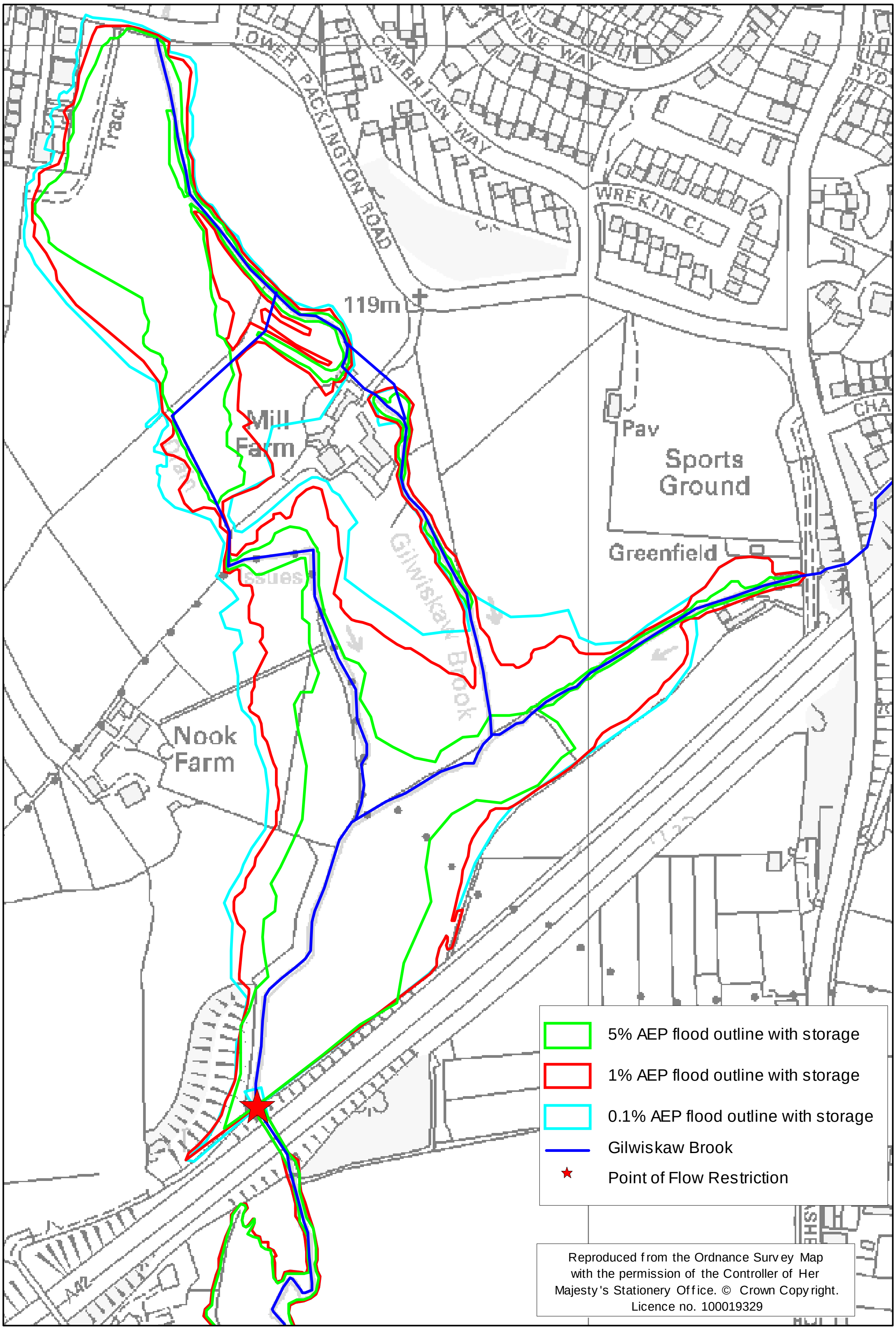



***Figure D9 – Scenario 2 Flood Storage Upstream of A42 for various design scenarios***

### D7.3 Urban Development

The previous sections have described the various flood storage options considered and the impact on flooding within Packington for the current situation. However, for the purpose of the SFRA, there is a need to identify whether the flood storage option is suitable to provide attenuation from increased urban development whilst providing some flooding protection to Packington village.

It is anticipated that development of the Gilwiskaw catchment will continue in the future through proposed development considered by developers and North West Leicestershire in the Local Plan and Urban Housing Potential Study along with infill development and paving of grassed areas. For the purposes of this study it is assumed that urban coverage will increase by 10% and that it will largely be on greenfield land and therefore will result in excess surface water runoff. The 10% urban coverage accounts for both new development and also increased impermeable areas through conservatories, sheds, patios, paving of grassed areas, driveways, etc.

Any potential increase in urban area of Ashby is likely to increase flows in Gilwiskaw Brook and, therefore, potential flooding in Packington both in terms of flood extent and depth of flooding. Flow through Packington will increase from 11.4 to 14.8 $m^3/s$ for the 1% AEP and 13.8 to 17.2 $m^3/s$ for the 1% AEP plus climate change scenario. This results in 23 and 26 properties at risk respectively in Packington Village.

The Flood Storage Option Scenario 2 has been modelled with the addition of Urban Development for the 1% AEP plus Climate Change. A 10% increase in urban development has been modelled by adjusting the URBEXT value in the FEH boundary units in ISIS. For this scenario a volume of 39,762$m^3$ was stored within the flood storage area and the flow is restricted to 5$m^3/s$ through Packington. There are two properties at risk of flooding with a maximum depth of flooding on Mill Street of 0.25m.

## D8.0 Conclusions

There is sufficient area upstream of the A42 to provide attenuation of existing runoff and potential runoff from development. With a flood storage volume of 39,762$m^3$ which attenuates the 1% AEP plus climate change and urban development, flow within Packington is restricted to 5$m^3/s$ and flooding is limited to 2 properties with some flooding of roads and gardens. Mapping of flood outlines has been undertaken using Lidar data. A more accurate assessment of the risk to these two properties should be undertaken by comparing the flood levels with the threshold levels of the properties. The flood storage option will reduce the risk to these two properties in terms of depth and velocity of flood water but additional flood protection measures may be required.

It is considered that the level of protection to Packington is very small in relation to the cost of the design of the storage area, site investigation, land acquisition and construction works along with the maintenance of the flood storage area following construction. However, if the council wants to adopt a “Developer Pays” principle then a solution may be forthcoming by permitting new development in the area.

In addition, the flood storage area had to be located downstream of Ashby to enable the maximum attenuation of flows upstream of Packington. There is no land available further upstream in Ashby. However, in providing attenuation downstream of development within Ashby, any development within Ashby itself will increase flows within Gilwiskaw Brook before it is attenuated within the flood storage basin. Increased flows in Gilwiskaw Brook may cause localised flooding within Ashby. Therefore, one large flood storage area is not considered a feasible option for attenuating runoff from several developments. Instead, attenuation should be provided for each of the development sites on the site itself to ensure there is no increase in flood risk downstream. Attenuation of developments on a case by case basis however will not provide the flood protection afforded by the flood storage option considered here which aims to alleviate existing flood risk whilst providing additional protection from flooding as a result of increased urban development and climate change.

It is recommended that a combination of flood storage areas both at the development site and at the A42 is considered to alleviate flood risk in Packingon whilst attenuating runoff from proposed development.

# Appendix E Packington Feasibility FEH Calculation Record

| ATKINS | CALCULATION CONTROL SHEET |
|---|---|
| **PROJECT:** NW Leicestershire SFRA | **Job No.** 5055053 |
| **PART OF PROJECT:** Packington Prefeasibility | **Calc. Ref.** |
| **CALCULATION TITLE:** FEH Calculation Record | **No. Calc. Shts.** |
| **FILE LOCATION:** P:\GBWAI\Water\Rivers & Coastal\Projects\5055053 NW Leicestershire SFRA\60_Work processes\Packington_hydrology | |

## CALCULATION SUMMARY

*This report provides a record of the calculations and decisions made during design flood estimation using the techniques of the Flood Estimation Handbook (Institute of Hydrology, 1999).*

**Purpose of Calculations**

To estimate inflows for a hydraulic model.

**Notes for Analyst:**

*This report does not attempt to cover all aspects of the hydrological study: its aim is to enable your work to be reproduced. In the main project report, you should consider adding information not given here, such as details of the rating review, the flood history and a comparison with previous studies.*

*All analysts doing work for the Environment Agency should have read Part 2 of the Agency guidelines on use of the FEH. You should also ensure that your copy of the FEH is up-to-date by checking the corrigenda page on the FEH website, www.nwl.ac.uk/ih/feh. Check there also for any reported errors in the software that you should be aware of.*

## REVISION HISTORY

| Revision Ref./ Date Issued | Date | Purpose and description of Amendments | Re-issued to |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## CHECKING AND REVIEW STATUS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| F1 | Final | K Hearn | | E Ainsworth | J Wright | May 2008 | |
| D1 | Draft | K Hearn | | E Ainsworth | J Wright | Dec 2007 | |
| Rev | Purpose | Originated | Checked | Reviewed | Authorised | Date | Client |
| | Description | WS ATKINS | | | | | |

# 1 CONTENTS

Page





ATKINS

# 1 METHOD STATEMENT

## Table 1.1: Overview of study

| Item | Comments |
|---|---|
| **Purpose of study** | SFRA<br>Prefeasibility study to determine if storage can be provided within catchment sufficient to alleviate existing flooding and allow additional development. |
| **Description of catchment** | |
| **Flood estimates required** | The 50% (2yr), 20% (5yr), 1% (100yr), 1%+allowance for climate change (20% increase in flows), 0.5% (200yr) and 0.1% (1000yr) AEP events. |
| **Approx. time available for study** | 4 months |

## Table 1.2: Flow or level data available

(at the sites of flood estimates or for nearby donor catchments)

| Watercourse | Station | Gauging authority number | NWA number (used in FEH) | Grid reference | Rating? | Period of available data | Source of data |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| **Comments on data quality (inc. rating) and any checks made** | Level gauge in Packington, with data since 2001 | | | | | | |

## Table 1.3: Other data available

| Item | Comments |
|---|---|
| **Flow gaugings (if planned to update rating curve)** | N/A |
| **Historic flood data** | Photos of flood event |
| **Extra data for other sites in pooling groups (if a major study)** | N/A |
| **Flood event data (if planned to use rainfall-runoff method)** | N/A |

### Table 1.3: Other data available

| Item | Comments |
|---|---|
| **Rainfall event data (if planned to use rainfall-runoff method)** | N/A |

### Table 1.4: Initial choice of approach

| Item | Comments |
|---|---|
| **Statistical, rainfall-runoff or hybrid approach?** | Hybrid<br>Rainfall runoff used in preference to ReFH as model requires calibration, and to maintain consistency with earlier studies. |
| **If statistical, single-site or pooled analysis?** | Pooled |
| **Review and update rating curves?** | No |
| **Any unusual factors to take into account? (e.g. highly permeable or urban catchment)** | No |

## 2 LOCATIONS WHERE FLOOD ESTIMATES REQUIRED

### Table 2.1: Summary of subject sites

| Site code | Watercourse | Site | Grid Reference | Cmt area | Any adjustments to catchment descriptors extracted from FEH CD-ROM 1999 |
|---|---|---|---|---|---|

## Table 2.1: Summary of subject sites

| Site code | Watercourse | Site | Grid Reference | Cmt area | Any adjustments to catchment descriptors extracted from FEH CD-ROM 1999 |
|---|---|---|---|---|---|
| **1** | Gilwiskaw | Upstream extent | SK 35850 15400 | 7.59 | Urbext 2007 – 0.1155 |
| **2** | Trib 1_Ashby | Upstream extent | SK 35900 15250 | 5.61 | Urbext 2007 – 0.0259 |
| **3** | Trib 2_Pack | u/s conf with Gilwiskaw Beck | SK 36050 14250 | 1.9 | Urbext 2007 – 0.0766 |
| **4** | Trib 3_Pack | u/s conf with Gilwiskaw Beck | SK 35850 13650 | 1.53 | |
| **5** | Lat 1 | Lateral inflow u/s of A42 | SK 35800 15100 | 0.651 | Urbext 2007 – 0.0766 |
| **6** | Lat 2 | Lateral inflow d/s of A42 to Trib 2 | SK 36050 14250 | 0.638 | Urbext 2007 – 0.0766 |
| **7** | Lat 3 | Lateral inflow from Trib 2 to Trib 3 | SK 35850 13650 | 0.297 | |
| **8** | Lat 4 | Lateral inflow from Trib 3 to d/s extent | SK 36050 12850 | 0.362 | |
| **9** | Gilwiskaw _u/s_A42 | u/s_A42 | SK 35800 15100 | 13.87 | Urbext 2007 – 0.0776 |
| **10** | Gilwiskaw _d/s_Pack | d/s_Pack | SK 36050 12850 | 18.59 | Urbext 2007 – 0.0715 |
| **Record how catchment descriptors checked** | | **Catchment boundaries checked using OS maps.** | | | |

## Table 2.3: Summary of catchment descriptors

| | Gilwiskaw | Trib 1_ashby | Trib 2_pack | Trib 3_pack | Lat 1 | Lat 2 | Lat 3 | Lat 4 | us_A42 | ds_pack |
|---|---|---|---|---|---|---|---|---|---|---|
| OS Ref | SK 35850 15400 | SK 35900 15250 | SK 36050 14250 | SK 35850 13650 | SK 35800 15100 | SK 36050 14250 | SK 35850 13650 | SK 36050 12850 | SK 35800 15100 | SK 36050 12850 |
| AREA | 7.59 | 5.61 | 1.9 | 1.53 | 0.651 | 0.638 | 0.297 | 0.362 | 13.87 | 18.59 |
| ALTBAR | 149 | 142 | 127 | 122 | 127 | 127 | 122 | 122 | 145 | 139 |
| ASPBAR | 162 | 232 | 234 | 122 | 234 | 234 | 122 | 122 | 186 | 185 |
| ASPVAR | 0.38 | 0.4 | 0.6 | 0.53 | 0.6 | 0.6 | 0.53 | 0.53 | 0.3 | 0.31 |
| BFIHOST | 0.589 | 0.568 | 0.55 | 0.632 | 0.55 | 0.55 | 0.632 | 0.632 | 0.577 | 0.583 |
| DPLBAR | 3.74 | 2.87 | 1.55 | 1.31 | 1.55 | 1.55 | 1.31 | 1.31 | 3.54 | 5.26 |
| DPSBAR | 36.8 | 29.9 | 27.3 | 31 | 27.3 | 27.3 | 31 | 31 | 33.8 | 32.9 |
| FARL | 0.996 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.998 | 0.998 |
| LDP | 6.31 | 4.61 | 3.08 | 2.14 | 3.08 | 3.08 | 2.14 | 2.14 | 6.7 | 9.33 |
| PROPWET | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| RMED-1H | 10.8 | 10.7 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.7 | 10.7 |
| RMED-1D | 31.3 | 31.9 | 31.8 | 30.8 | 31.8 | 31.8 | 30.8 | 30.8 | 31.5 | 31.4 |
| RMED-2D | 37.8 | 38.6 | 38.8 | 37.5 | 38.8 | 38.8 | 37.5 | 37.5 | 38.1 | 38.1 |
| SAAR | 678 | 682 | 665 | 654 | 665 | 665 | 654 | 654 | 679 | 674 |
| SAAR4170 | 701 | 699 | 692 | 666 | 692 | 692 | 666 | 666 | 699 | 694 |
| SPRHOST | 27.25 | 29.07 | 28.54 | 34.53 | 28.54 | 28.54 | 34.53 | 34.53 | 28.23 | 29.01 |
| URBCONC1990 | 0.788 | 0.545 | 0.664 | -999999 | 0.664 | 0.664 | -999999 | -999999 | 0.748 | 0.727 |
| URBEXT1990 | 0.1091 | 0.0245 | 0.0723 | 0.0008 | 0.0723 | 0.0723 | 0.0008 | 0.0008 | 0.0733 | 0.0675 |
| URBLOC1990 | 0.659 | 0.654 | 0.631 | -999999 | 0.631 | 0.631 | -999999 | -999999 | 0.751 | 0.905 |
| C | -0.02684 | -0.02734 | -0.02722 | -0.028 | -0.02722 | -0.02722 | -0.028 | -0.028 | -0.02707 | -0.02723 |
| D1 | 0.34648 | 0.35424 | 0.35314 | 0.34619 | 0.35314 | 0.35314 | 0.34619 | 0.34619 | 0.34966 | 0.34954 |
| D2 | 0.30988 | 0.32297 | 0.33391 | 0.33949 | 0.33391 | 0.33391 | 0.33949 | 0.33949 | 0.31598 | 0.32153 |
| D3 | 0.2742 | 0.28422 | 0.28501 | 0.28461 | 0.28501 | 0.28501 | 0.28461 | 0.28461 | 0.27867 | 0.28021 |
| E | 0.30536 | 0.30695 | 0.30608 | 0.30651 | 0.30608 | 0.30608 | 0.30651 | 0.30651 | 0.30604 | 0.30612 |
| F | 2.40327 | 2.39856 | 2.40018 | 2.38868 | 2.40018 | 2.40018 | 2.38868 | 2.38868 | 2.40105 | 2.39918 |
| C(1 km) | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 | -0.028 |
| D1(1 km) | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.352 |
| D2(1 km) | 0.336 | 0.336 | 0.344 | 0.344 | 0.344 | 0.344 | 0.344 | 0.344 | 0.336 | 0.347 |
| D3(1 km) | 0.283 | 0.283 | 0.285 | 0.285 | 0.285 | 0.285 | 0.285 | 0.285 | 0.283 | 0.284 |
| E(1 km) | 0.307 | 0.307 | 0.306 | 0.306 | 0.306 | 0.306 | 0.306 | 0.306 | 0.307 | 0.307 |
| F(1 km) | 2.398 | 2.398 | 2.389 | 2.389 | 2.389 | 2.389 | 2.389 | 2.389 | 2.398 | 2.38 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| urbext 2007 | 0.1155 | 0.0259 | 0.0766 | 0.0008 | 0.0766 | 0.0766 | 0.0008 | 0.0008 | 0.0776 | 0.0715 |

## 3 RECORD OF DATA USED

*Flood peak data from HiFlows-UK downloaded from the EA website http://www.environment-agency.gov.uk/hiflowsuk in August 2005 and used.*

# 4 STATISTICAL METHOD

## Table 4.1: Estimate of QMED

| Site Code | Method: AM, POT, DT or CD | Initial estimate of QMED ($m^3/s$) from catchment descriptors (FEH vol 3, Ch 3) | If DT, numbers of donor/analogue sites used (see Table 4.2) Include weighting factors apportioned to analogue sites | If multi-site analysis, QMED estimates from individual station adjustment ratios * | Final estimate of QMED ($m^3/s$) |
|---|---|---|---|---|---|
| u/s_A42 | **DT** | 2.26 | Dowles, Witham & Chater | | 3.37 |
| d/s_Pack | **DT** | 2.79 | Dowles, Witham & Chater | | 4.15 |

**AM – Annual maxima, POT – Peaks Over Threshold, DT – Catchment descriptors with data transfer, CD – Catchment descriptors**

## Table 4.2: Donor and analogue sites for QMED

| Gauge No. | Station | Suitable for pooling? | AM or POT | QMED from flow data (A) | QMED from CD (B) | Adj ratio (A/B) |
|---|---|---|---|---|---|---|
| 54034 | Dowles brook@Oak Cottage | | AM | 9.550 | 4.66 | 2.051 |
| 30017 | Witham@Colsterworth | | AM | 5.920 | 4.27 | 1.386 |
| 31010 | Chater@Fosters Bridge | | AM | 10.300 | 8.52 | 1.208 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## Table 4.3: Check of QMED using Channel Dimensions

| Site Code | Watercourse | Location (eq model chainage) | BCW (Bankfull Channel Width in metres) | QMED from Channel Dimensions | Comment /comparison with estimate above | Final value of QMED used |
|---|---|---|---|---|---|---|
| N/A | | | | | | |
| | | | | | | |
| | | | | | | |
| **See FEH Volume 3 Section 5.2 (page 24)** | | | | | | |

## Table 4.4: Derivation of pooling groups

(**Note:** *Several subject sites may use the same pooling group*)

| Name | Site code for which group initially derived | Target return period (years) | Changes made to default pooling group produced by WINFAP-FEH. Note also any sites that were investigated but retained in the group. |
|---|---|---|---|

## Table 4.4: Derivation of pooling groups

(**Note:** *Several subject sites may use the same pooling group*)

| Name | Site code for which group initially derived | Target return period (years) | Changes made to default pooling group produced by WINFAP-FEH. Note also any sites that were investigated but retained in the group. |
|---|---|---|---|
| u/s_A42 | u/s_A42 | 100 | **Removed:**<br>32029 – only 5 years of data<br>40006 – very steep growth curve dominated by a single extreme event beyond the verified rating extents<br>**Added:**<br>33031, 20005<br>**Investigated:**<br>25019 – has a very steep growth curve, however historic flood marks do support the more extreme event flows |
| d/s_pack | d/s_pack | 100 | **Removed:**<br>40006 – very steep growth curve dominated by a single extreme event beyond the verified rating extents<br>**Added:**<br>20005<br>**Investigated:**<br>25019 – has a very steep growth curve, however historic flood marks do support the more extreme event flows |

## Table 4.5: Derivation of flood growth curves at each subject site

| Site code | Method:<br>SS – Single site<br>P – Pooled<br>J – Joint Analysis<br>H – Incorporating historical data | If J, weighting factor given to subject site | Distribution(s) chosen and reason | Parameters of chosen distribution(s) |
|---|---|---|---|---|
| **u/s_A42** | P | - | GEV recommended in FEH and gives acceptable fit | Location: 0.812<br>Scale: 0.515<br>Shape: 0.017<br>Bound: 31.575 |
| **d/s_pack** | P | - | GEV recommended in FEH and gives acceptable fit | Location: 0.811<br>Scale: 0.518<br>Shape: 0.013<br>Bound: 40.170 |

**General Notes: u/s A42, GEV and Pearson III distributions gave acceptable fit and both were investigated. The two distributions gave very similar growth curves. GEV used as it gave slightly higher flows**
**d/s_pack – GL and GEV distributions gave acceptable fit and both were investigated, though the goodness of fit measure suggested the GEV was the better fit. The two distributions gave very similar growth curves at lower return periods but the GL was much steeper beyond Q100. GEV used as it gave flows more consistent with the flows derived for u/s A42**

## Table 4.6 Statistical Method Estimate of Peak Flows

| Name | Flood peak ($m^3$/s) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | |
|---|---|---|---|---|---|
| | 50% (2) | 5% (20) | 1% (100) | 0.5% (200) | 0.1% (1000) |
| **u/s_A42** | 3.37 | 7.1 | 9.3 | 10.2 | 12.3 |
| **d/s_pack** | 4.15 | 8.8 | 11.7 | 12.9 | 15.6 |

# 5 RAINFALL-RUNOFF METHOD

## Table 5.1: Derivation of parameters for rainfall-runoff model

Methods: FEA : Flood event analysis (see Table 5.3)
LAG : Catchment lag
DT : Catchment descriptors with data transfer from donor catchment
CD : Catchment descriptors alone
BFI : SPR derived from baseflow index calculated from flow data

| Site code | Critical Duration | Rural (R) or urban (U) | Tp(0): method* | Tp(0): value (hours) | SPR: method* | SPR: value (%) | BF: method* | BF: value ($m^3$/s)- Q100 | If DT, numbers of donor sites used (see Table 5.2) and reasons |
|---|---|---|---|---|---|---|---|---|---|
| Gilwiskaw | 5.98 | R | CD | 3.44 | CD | 27.25 | CD | 0.092 | - |
| Trib 1_Ashby | 8.95 | R | CD | 5.19 | CD | 29.07 | CD | 0.070 | - |
| Trib 2_Pack | 5.05 | R | CD | 2.91 | CD | 28.54 | CD | 0.021 | - |
| Trib 3_Pack | 6.61 | R | CD | 3.87 | CD | 34.53 | CD | 0.015 | - |
| Lat 1 | 2.84 | R | CD | 1.58 | CD | 28.54 | CD | 0.007 | - |
| Lat 2 | 2.84 | R | CD | 1.58 | CD | 28.54 | CD | 0.007 | - |
| Lat 3 | 4.02 | R | CD | 2.30 | CD | 34.53 | CD | 0.003 | - |
| Lat 4 | 4.02 | R | CD | 2.30 | CD | 34.53 | CD | 0.004 | - |
| Gilwiskaw _u/s_A42 | 7.25 | R | CD | 4.20 | CD | 28.23 | CD | 0.170 | - |
| Gilwiskaw _d/s_Pack | 9.28 | R | CD | 5.42 | CD | 29.01 | CD | 0.219 | - |

## Table 5.2: Donor sites for rainfall-runoff parameters

| No. | Watercourse | Station | Tp(0) from data (A) | Tp(0) from CDs (B) | Adj. ratio for Tp(0) (A/B) | SPR from data (C) | SPR from CDs (D) | Adj. ratio for SPR (C/D) | BF from data (E) | BF from CDs (F) | Adj. ratio for BF (E/F) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N/A | | | | | | | | | | |

## Table 5.3: Availability of river and rainfall event data

Enter Y if data available, N if not available, I if record intermittent

| Event | Event peak Packington (mAOD) | Data availability | |
|---|---|---|---|
| | | Packington level gauge | Overseal TBR |
| July 2001 | 106.0 | 15 min data available | 15 min data available |
| Oct 2004 | 105.3 | 15 min data available | 15 min data available |
| June 2007 | 105.9 | 15 min data available | 15 min data available |

Verification undertaken for 3 events, results were very good for Oct 2004 but peak underpredicted for July 2001. June 2007 the shape of the hydrograph did not fit suggesting a problem with the rainfall profile.
No changes were made to hydrology model as a result of verification.

## Table 5.4: FEH rainfall-runoff model peak flows–catchment wide storm used.

| Site code | Design storm duration (hours) | Flood peak ($m^3$/s) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). |
|---|---|---|

## Table 5.4: FEH rainfall-runoff model peak flows–catchment wide storm used.

| Site code | Design storm duration (hours) | Flood peak ($m^3/s$) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50% (2) | 5% (20) | 1% (100) | 0.5% (200) | 0.1% (1000) | | | | |
| Gilwiskaw | 9.25 | 2.1 | 4.8 | 7.4 | 8.8 | 13.6 | | | | |
| Trib 1_Ashby | 9.25 | 1.2 | 2.8 | 4.3 | 5.1 | 7.9 | | | | |
| Trib 2_Pack | 9.25 | 0.6 | 1.3 | 2.0 | 2.4 | 3.7 | | | | |
| Trib 3_Pack | 9.25 | 0.4 | 1.0 | 1.5 | 1.8 | 2.7 | | | | |
| Lat 1* | 9.25 | 0.4 | 0.6 | 0.9 | 1.1 | 1.6 | | | | |
| Lat 2 | 9.25 | 0.2 | 0.6 | 0.9 | 1.0 | 1.6 | | | | |
| Lat 3 | 9.25 | 0.1 | 0.2 | 0.4 | 0.4 | 0.7 | | | | |
| Lat 4 | 9.25 | 0.1 | 0.3 | 0.4 | 0.5 | 0.8 | | | | |
| Gilwiskaw _u/s_A42 | 9.25 | 3.5 | 7.7 | 11.6 | 13.8 | 21.2 | | | | |
| Gilwiskaw _d/s_Pack | 9.25 | 4.5 | 10.1 | 14.6 | 18.7 | 27.6 | | | | |

* note, lateral 1 is the inflow to a field drain in the hydraulic model, a minimum flow of 0.37 is required for a stable model run. This minimum flow is higher than Lat 1 QMED is very small compared to the overall flows in the system

## Table 5.5: ReFH peak flows

| Site code | Design storm duration (hours) | Flood peak ($m^3/s$) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50% (2) | 20% (5) | 10% (10) | 4% (25) | 2% (50) | 1.33% (75) | 1% (100) | 0.5% (200) | 0.1% (1000) |
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# 6 SUMMARY OF RESULTS

## Table 6.1: Overview of results

| Item | Comments |
|---|---|
| **Final choice of method and reasons** | The results from the FEH rainfall-runoff are higher than statistical. Rainfall runoff method used as more conservative flood estimates are appropriate for this study. Pre feasibility is to assess if sufficient storage volume can be accommodated on watercourse. Conservative flows ensures that this is adequately accounted for.<br>More detailed assessment of hydrology would be required at detailed design stage, with further calibration of model. |

## Table 6.3: Final flood estimates for each site

*Note: If statistical method used alone, simply enter "See Table 4.6"*
*If rainfall-runoff method used alone, simply enter "See Table 5.4"*

| Name | Site Code | Method Code | Flood peak ($m^3$/s) for the following percentage chance of an event occurring in any one year (with return periods in years in brackets). | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 50% (2) | 20% (5) | 10% (10) | 4% (25) | 2% (50) | 1.33% (75) | 1% (100) | 0.5% (200) |
| See Table 5.4 | | | | | | | | | | |

## Table 6.4: Event Return Periods

Approximate flows for events have been estimated. An approximate model rating at Packington gauge has been used to estimate flows for each event. (this was used in preference to the model flow which was not well represented for June 2007 and underpredicted for June 2001). A range of flows is given which represents the sensitivity of the model to hydraulic parameters eg mannings values. Return periods assigned to thee flows are based on the rainfall runoff flows in Table 5.4. Note flows at Packington gauge are almost the same as us_A42.

| Event | Event peak Packington (mAOD) | Data availability | |
|---|---|---|---|
| | | Approximate flow | Return Period |
| July 2001 | 106.0 | 10 to 12 | Q50 - Q100 |
| Oct 2004 | 105.3 | 4.7 | QMED - Q5 |
| June 2007 | 105.9 | 8 to 10 | Q25 - Q50 |

# Appendix F Packington Feasibility Model Results

| ISIS Node | Q20 Max Stage (mAOD) | Q20 Max Flow (m3/s) | Q100 Max Stage (mAOD) | Q100 Max Flow (m3/s) | Q100 +20% Max Stage (mAOD) | Q100 +20% Max Flow (m3/s) | Q1000 Max Stage (mAOD) | Q1000 Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|
| Gilwiskaw | 117.40 | 4.85 | 117.66 | 7.41 | 117.77 | 8.89 | 118.02 | 13.60 |
| Trib1_ashby | 113.88 | 2.77 | 114.08 | 4.25 | 114.19 | 5.11 | 114.48 | 7.88 |
| Trib2_pack | 104.59 | 1.32 | 104.84 | 2.02 | 104.99 | 2.43 | 105.24 | 3.74 |
| Trib3_pack | 101.12 | 0.98 | 101.22 | 1.50 | 101.25 | 1.80 | 101.37 | 2.73 |
| Lat1 | 116.52 | 0.58 | 116.58 | 0.89 | 116.64 | 1.06 | 116.76 | 1.64 |
| Lat2 | -9999.99 | 0.56 | -9999.99 | 0.87 | -9999.99 | 1.04 | -9999.99 | 1.60 |
| Lat2a | 107.17 | 0.10 | 107.75 | 0.16 | 107.90 | 0.19 | 108.20 | 0.30 |
| Lat2b | 105.67 | 0.46 | 105.97 | 0.71 | 106.14 | 0.85 | 106.31 | 1.31 |
| Lat3 | -9999.99 | 0.25 | -9999.99 | 0.38 | -9999.99 | 0.45 | -9999.99 | 0.69 |
| Lat3a | 103.11 | 0.15 | 103.33 | 0.22 | 103.48 | 0.27 | 103.82 | 0.41 |
| Lat3b | 102.10 | 0.10 | 102.30 | 0.15 | 102.40 | 0.19 | 102.75 | 0.28 |
| Lat4 | -9999.99 | 0.30 | -9999.99 | 0.46 | -9999.99 | 0.55 | -9999.99 | 0.84 |
| Lat4a | 101.12 | 0.18 | 101.22 | 0.27 | 101.25 | 0.33 | 101.37 | 0.50 |
| Lat4b | 99.67 | 0.08 | 99.80 | 0.12 | 99.91 | 0.15 | 100.25 | 0.22 |
| Lat4c | 98.25 | 0.02 | 98.44 | 0.02 | 98.56 | 0.03 | 98.84 | 0.04 |
| Lat4d | 96.30 | 0.03 | 96.36 | 0.04 | 96.41 | 0.05 | 96.52 | 0.07 |
| TRIB01_0360 | 113.88 | 2.77 | 114.08 | 4.25 | 114.19 | 5.11 | 114.48 | 7.88 |
| TRIB01_0340D | 113.79 | 2.77 | 113.98 | 4.25 | 114.07 | 5.11 | 114.34 | 7.88 |
| TRIB01_0340E | 113.79 | 2.77 | 113.98 | 4.25 | 114.07 | 5.11 | 114.34 | 7.88 |
| TRIB01_0310i | 113.68 | 2.77 | 113.86 | 4.25 | 113.96 | 5.11 | 114.24 | 7.88 |
| TRIB01_0280D | 113.58 | 2.77 | 113.78 | 4.25 | 113.89 | 5.11 | 114.20 | 7.88 |
| TRIB01_0280E | 113.50 | 2.77 | 113.65 | 4.25 | 113.73 | 5.11 | 113.95 | 7.88 |
| TRIB01_0268 | 113.39 | 2.77 | 113.55 | 4.25 | 113.64 | 5.11 | 113.85 | 7.88 |
| TRIB01_0225i | 113.07 | 2.77 | 113.29 | 4.25 | 113.39 | 5.11 | 113.61 | 7.88 |
| TRIB01_0182 | 112.77 | 2.77 | 113.00 | 4.25 | 113.12 | 5.10 | 113.33 | 7.88 |
| TRIB01_0145i | 112.53 | 2.77 | 112.72 | 4.25 | 112.81 | 5.10 | 113.03 | 7.88 |
| TRIB01_0108 | 112.19 | 2.77 | 112.37 | 4.25 | 112.45 | 5.10 | 112.68 | 7.88 |
| TRIB01_0083i | 111.94 | 2.77 | 112.12 | 4.25 | 112.20 | 5.10 | 112.41 | 7.88 |
| TRIB01_0057i | 111.71 | 2.77 | 111.88 | 4.25 | 111.96 | 5.10 | 112.16 | 7.88 |
| TRIB01_0032 | 111.63 | 2.77 | 111.78 | 4.25 | 111.84 | 5.10 | 112.01 | 7.88 |
| TRIB01_0000H | 111.61 | 2.77 | 111.74 | 4.26 | 111.79 | 5.11 | 111.93 | 7.88 |
| TRIB01_0000I | 111.60 | 2.77 | 111.71 | 4.26 | 111.76 | 5.11 | 111.87 | 7.88 |
| DRAIN_4910R | 116.52 | 0.00 | 116.58 | 0.00 | 116.64 | 0.00 | 116.76 | 0.01 |
| DRAIN_4896R | 116.52 | 0.00 | 116.58 | 0.00 | 116.64 | 0.00 | 116.76 | 0.00 |
| DRAIN_4882R | 116.52 | 0.00 | 116.58 | 0.22 | 116.64 | 0.62 | 116.76 | 2.17 |
| DRAIN_4869R | 116.52 | 0.00 | 116.58 | 0.14 | 116.64 | 0.40 | 116.76 | 1.46 |
| DRAIN_0533 | 116.52 | 0.58 | 116.58 | 0.91 | 116.64 | 1.65 | 116.76 | 4.60 |
| DRAIN_0503 | 116.12 | 0.58 | 116.19 | 0.90 | 116.26 | 1.64 | 116.38 | 4.60 |
| DRAIN_0488i | 115.98 | 0.58 | 116.02 | 0.91 | 116.08 | 1.64 | 116.21 | 4.60 |
| DRAIN_0473H | 115.81 | 0.58 | 115.84 | 0.93 | 115.89 | 1.67 | 115.99 | 4.60 |
| DRAIN_0473I | 115.81 | 0.58 | 115.84 | 0.93 | 115.88 | 1.67 | 115.98 | 4.60 |
| DRAIN_0458i | 115.45 | 0.58 | 115.48 | 0.93 | 115.53 | 1.67 | 115.65 | 4.60 |
| DRAIN_0443 | 115.18 | 0.58 | 115.21 | 0.92 | 115.28 | 1.67 | 115.44 | 4.60 |
| DRAIN_0425i | 115.12 | 0.58 | 115.15 | 0.91 | 115.20 | 1.65 | 115.34 | 4.60 |
| DRAIN_0408 | 114.99 | 0.58 | 115.02 | 0.90 | 115.07 | 1.65 | 115.25 | 4.60 |
| DRAIN_0378 | 114.72 | 0.58 | 114.81 | 0.90 | 114.92 | 1.65 | 115.19 | 4.59 |
| DRAIN_0336 | 114.05 | 0.58 | 114.16 | 0.90 | 114.33 | 1.65 | 114.71 | 4.59 |
| DRAIN_0292 | 113.25 | 0.58 | 113.35 | 0.90 | 113.51 | 1.65 | 113.85 | 4.59 |
| DRAIN_0252i | 112.62 | 0.57 | 112.70 | 0.90 | 112.84 | 1.65 | 113.14 | 4.59 |
| DRAIN_0212 | 112.11 | 0.57 | 112.22 | 0.90 | 112.35 | 1.65 | 112.62 | 4.59 |
| DRAIN_0154 | 111.69 | 0.57 | 111.80 | 0.91 | 111.99 | 1.65 | 112.33 | 4.59 |
| DRAIN_0103 | 111.28 | 0.57 | 111.45 | 0.91 | 111.59 | 1.65 | 111.89 | 4.59 |
| DRAIN_0052 | 111.17 | 0.57 | 111.30 | 0.90 | 111.36 | 1.65 | 111.53 | 4.59 |
| DRAIN_0026 | 111.17 | 0.57 | 111.29 | 0.90 | 111.35 | 1.64 | 111.53 | 4.58 |
| DRAIN_0000 | 111.17 | 0.56 | 111.29 | 0.89 | 111.35 | 1.63 | 111.52 | 4.56 |
| GILW01_5100 | 117.40 | 4.85 | 117.66 | 7.41 | 117.77 | 8.89 | 118.02 | 13.60 |

| | Q20 | | Q100 | | Q100 +20% | | Q1000 | |
|---|---|---|---|---|---|---|---|---|
| ISIS Node | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| GILW01_5086i | 117.39 | 4.85 | 117.64 | 7.41 | 117.75 | 8.89 | 118.01 | 13.60 |
| GILW01_5073 | 117.37 | 4.85 | 117.63 | 7.41 | 117.74 | 8.89 | 118.00 | 13.60 |
| GILW01_5053 | 117.33 | 4.85 | 117.59 | 7.41 | 117.70 | 8.89 | 117.95 | 13.60 |
| GILW01_5031 | 117.22 | 4.85 | 117.43 | 7.41 | 117.53 | 8.89 | 117.76 | 13.60 |
| GILW01_5013 | 117.21 | 4.85 | 117.42 | 7.41 | 117.52 | 8.89 | 117.75 | 13.60 |
| GILW01_4995 | 117.17 | 4.85 | 117.36 | 7.41 | 117.46 | 8.89 | 117.68 | 13.60 |
| GILW01_4968 | 116.97 | 4.85 | 117.20 | 7.41 | 117.28 | 8.89 | 117.46 | 13.60 |
| GILW01_4950 | 116.93 | 4.84 | 117.16 | 7.41 | 117.24 | 8.89 | 117.42 | 13.60 |
| GILW01_4925 | 116.90 | 4.84 | 117.13 | 7.41 | 117.20 | 8.89 | 117.36 | 13.60 |
| GILW01_4917i | 116.89 | 4.84 | 117.12 | 7.41 | 117.19 | 8.89 | 117.34 | 13.60 |
| GILW01_4910 | 116.88 | 4.84 | 117.10 | 7.41 | 117.17 | 8.89 | 117.31 | 13.60 |
| GILW01_4910R | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.01 |
| GILW01_4896 | 116.86 | 4.84 | 117.08 | 7.41 | 117.14 | 8.89 | 117.26 | 13.59 |
| GILW01_4896R | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_4882 | 116.85 | 4.84 | 117.07 | 7.41 | 117.14 | 8.89 | 117.26 | 13.59 |
| GILW01_4882R | -9999.99 | 0.00 | -9999.99 | 0.22 | -9999.99 | 0.62 | -9999.99 | 2.17 |
| GILW01_4869 | 116.77 | 4.84 | 117.00 | 7.19 | 117.07 | 8.27 | 117.20 | 11.43 |
| GILW01_4869R | -9999.99 | 0.00 | -9999.99 | 0.14 | -9999.99 | 0.40 | -9999.99 | 1.46 |
| GILW01_4842 | 116.53 | 4.84 | 116.74 | 7.05 | 116.82 | 7.87 | 116.96 | 9.97 |
| GILW01_4826 | 116.54 | 4.84 | 116.78 | 7.05 | 116.86 | 7.87 | 117.02 | 9.97 |
| GILW01_4820i | 116.49 | 4.84 | 116.75 | 7.05 | 116.83 | 7.87 | 116.99 | 9.97 |
| GILW01_4814 | 116.30 | 4.84 | 116.52 | 7.05 | 116.59 | 7.87 | 116.74 | 9.97 |
| GILW01_4805i | 116.16 | 4.84 | 116.39 | 7.05 | 116.46 | 7.87 | 116.61 | 9.97 |
| GILW01_4795 | 115.99 | 4.84 | 116.24 | 7.05 | 116.31 | 7.87 | 116.48 | 9.97 |
| GILW01_4786i | 115.81 | 4.84 | 116.07 | 7.05 | 116.16 | 7.87 | 116.35 | 9.97 |
| GILW01_4777H | 115.62 | 0.00 | 115.90 | 0.00 | 116.01 | 0.00 | 116.25 | 0.00 |
| GILW01_4777L | 115.62 | 4.84 | 115.90 | 7.05 | 116.01 | 7.87 | 116.25 | 9.97 |
| GILW01_4777C | 115.62 | 4.84 | 115.90 | 7.05 | 116.01 | 7.87 | 116.25 | 9.97 |
| GILW01_4777I | 115.55 | 0.00 | 115.77 | 0.00 | 115.84 | 0.00 | 115.98 | 0.00 |
| GILW01_4771C | 115.55 | 4.84 | 115.77 | 7.05 | 115.84 | 7.87 | 115.98 | 9.97 |
| GILW01_4771M | 115.55 | 4.84 | 115.77 | 7.05 | 115.84 | 7.87 | 115.98 | 9.97 |
| GILW01_4759i | 115.34 | 4.84 | 115.56 | 7.05 | 115.62 | 7.87 | 115.76 | 9.97 |
| GILW01_4747i | 115.11 | 4.84 | 115.31 | 7.05 | 115.38 | 7.87 | 115.52 | 9.97 |
| GILW01_4735H | 114.81 | 4.84 | 115.00 | 7.05 | 115.06 | 7.87 | 115.20 | 9.97 |
| GILW01_4735I | 114.74 | 4.84 | 114.91 | 7.05 | 114.97 | 7.87 | 115.09 | 9.97 |
| GILW01_4713i | 113.76 | 4.84 | 113.92 | 7.05 | 113.97 | 7.87 | 114.07 | 9.97 |
| GILW01_4692 | 113.09 | 4.84 | 113.26 | 7.05 | 113.32 | 7.87 | 113.45 | 9.97 |
| GILW01_4667i | 112.77 | 4.84 | 112.98 | 7.05 | 113.04 | 7.87 | 113.17 | 9.97 |
| GILW01_4642 | 112.58 | 4.84 | 112.82 | 7.05 | 112.88 | 7.87 | 113.03 | 9.97 |
| GILW01_4615i | 112.40 | 4.84 | 112.64 | 7.05 | 112.71 | 7.87 | 112.85 | 9.97 |
| GILW01_4587i | 112.20 | 4.84 | 112.42 | 7.05 | 112.50 | 7.87 | 112.64 | 9.97 |
| GILW01_4560 | 111.91 | 4.84 | 112.05 | 7.05 | 112.10 | 7.87 | 112.23 | 9.97 |
| GILW01_4504 | 111.67 | 4.84 | 111.79 | 7.05 | 111.83 | 7.87 | 111.93 | 9.97 |
| GILW01_4475A | 111.60 | 4.84 | 111.71 | 7.04 | 111.76 | 7.86 | 111.87 | 9.96 |
| GILW01_4475B | 111.60 | 7.32 | 111.71 | 10.90 | 111.76 | 12.52 | 111.87 | 17.23 |
| GILW01_4446 | 111.47 | 7.32 | 111.59 | 10.90 | 111.63 | 12.52 | 111.74 | 17.23 |
| GILW01_4398i | 111.31 | 7.32 | 111.43 | 10.90 | 111.47 | 12.52 | 111.60 | 17.24 |
| GILW01_4351A | 111.17 | 7.32 | 111.29 | 10.90 | 111.35 | 12.53 | 111.52 | 17.25 |
| GILW01_4351B | 111.17 | 7.69 | 111.29 | 11.60 | 111.35 | 13.91 | 111.52 | 21.30 |
| GILW01_4327i | 111.08 | 7.68 | 111.20 | 11.60 | 111.26 | 13.91 | 111.46 | 21.30 |
| GILW01_4285i | 110.86 | 7.68 | 110.99 | 11.60 | 111.05 | 13.91 | 111.37 | 21.29 |
| GILW01_4302 | 110.94 | 7.68 | 111.08 | 11.60 | 111.14 | 13.91 | 111.40 | 21.30 |
| GILW01_4267i | 110.80 | 7.68 | 110.92 | 11.60 | 110.98 | 13.91 | 111.35 | 21.29 |
| GILW01_4249 | 110.76 | 7.68 | 110.86 | 11.60 | 110.92 | 13.92 | 111.33 | 21.29 |
| GILW01_4233i | 110.71 | 7.68 | 110.84 | 11.60 | 110.87 | 13.91 | 111.32 | 21.28 |
| GILW01_4217i | 110.66 | 7.68 | 110.75 | 15.04 | 110.87 | 13.91 | 111.32 | 21.28 |

| ISIS Node | Q20 Max Stage (mAOD) | Q20 Max Flow (m3/s) | Q100 Max Stage (mAOD) | Q100 Max Flow (m3/s) | Q100 +20% Max Stage (mAOD) | Q100 +20% Max Flow (m3/s) | Q1000 Max Stage (mAOD) | Q1000 Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|
| GILW01_4200 | 110.22 | 7.68 | 110.61 | 11.60 | 110.76 | 13.91 | 111.31 | 21.27 |
| GILW01_4193i | 110.08 | 7.68 | 110.56 | 11.60 | 110.75 | 13.91 | 111.31 | 21.27 |
| GILW01_4185 | 110.12 | 7.68 | 110.57 | 11.59 | 110.75 | 13.91 | 111.31 | 21.26 |
| GILW01_4168i | 110.08 | 7.68 | 110.55 | 11.59 | 110.74 | 13.91 | 111.31 | 21.26 |
| GILW01_4152i | 110.06 | 7.68 | 110.55 | 11.59 | 110.74 | 13.91 | 111.31 | 21.25 |
| GILW01_4135 | 110.04 | 7.68 | 110.54 | 11.59 | 110.73 | 13.90 | 111.31 | 21.25 |
| GILW01_4097D | 110.01 | 7.68 | 110.52 | 11.58 | 110.72 | 13.90 | 111.29 | 21.25 |
| GILW01_4097E | 109.86 | 7.68 | 110.21 | 11.58 | 110.32 | 13.90 | 110.58 | 21.25 |
| GILW01_4043 | 109.72 | 7.68 | 110.12 | 11.58 | 110.24 | 13.90 | 110.49 | 21.25 |
| GILW01_3981 | 109.01 | 7.68 | 109.22 | 11.59 | 109.34 | 13.90 | 109.66 | 21.25 |
| GILW01_3934i | 108.73 | 7.68 | 108.83 | 11.59 | 108.88 | 13.89 | 109.03 | 21.25 |
| GILW01_3888 | 108.59 | 7.67 | 108.66 | 11.59 | 108.68 | 13.90 | 108.81 | 21.25 |
| GILW01_3795 | 107.92 | 7.67 | 108.09 | 11.59 | 108.18 | 13.89 | 108.41 | 21.25 |
| GILW01_3728 | 107.54 | 7.67 | 107.85 | 11.56 | 107.99 | 13.88 | 108.27 | 21.24 |
| GILW01_3647 | 107.28 | 7.67 | 107.77 | 11.50 | 107.92 | 13.86 | 108.22 | 21.23 |
| GILW01_3585D | 107.18 | 7.67 | 107.75 | 11.45 | 107.91 | 13.83 | 108.20 | 21.22 |
| GILW01_3585E | 107.17 | 7.67 | 107.75 | 11.45 | 107.90 | 13.83 | 108.20 | 21.22 |
| GILW01_3530 | 107.03 | 7.70 | 107.74 | 11.44 | 107.90 | 13.87 | 108.20 | 21.30 |
| GILW01_3516 | 107.03 | 7.70 | 107.74 | 11.43 | 107.90 | 13.86 | 108.19 | 21.30 |
| GILW01_3516H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.11 | -9999.99 | 1.79 |
| GILW01_3511I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.11 | -9999.99 | 1.79 |
| GILW01_3511D | 107.02 | 7.69 | 107.73 | 11.43 | 107.90 | 13.75 | 108.19 | 19.51 |
| GILW01_3511E | 106.96 | 7.69 | 107.53 | 11.43 | 107.69 | 13.75 | 108.02 | 19.51 |
| GILW01_3494i | 106.94 | 7.69 | 107.52 | 11.42 | 107.69 | 13.85 | 108.02 | 21.29 |
| GILW01_3477 | 106.87 | 7.69 | 107.52 | 11.41 | 107.68 | 13.85 | 108.01 | 21.29 |
| GILW01_3425 | 106.79 | 7.69 | 107.50 | 11.39 | 107.67 | 13.83 | 108.00 | 21.29 |
| GILW01_3425H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.74 | -9999.99 | 4.02 |
| GILW01_3418I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.74 | -9999.99 | 4.02 |
| GILW01_3418D | 106.78 | 7.69 | 107.50 | 11.39 | 107.67 | 13.11 | 108.00 | 17.27 |
| GILW01_3418E | 106.70 | 7.69 | 107.18 | 11.39 | 107.37 | 13.11 | 107.72 | 17.27 |
| GILW01_3335 | 106.64 | 7.68 | 107.15 | 11.37 | 107.35 | 13.80 | 107.70 | 21.30 |
| GILW01_3273H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.02 | -9999.99 | 2.66 |
| GILW01_3273 | 106.56 | 7.68 | 107.13 | 11.36 | 107.33 | 13.79 | 107.68 | 21.30 |
| GILW01_3266I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.02 | -9999.99 | 2.66 |
| GILW01_3266D | 106.54 | 7.68 | 107.13 | 11.36 | 107.33 | 13.77 | 107.68 | 18.64 |
| GILW01_3266E | 106.41 | 7.68 | 106.67 | 11.36 | 106.79 | 13.77 | 107.06 | 18.64 |
| GILW01_3203 | 105.98 | 7.68 | 106.26 | 11.36 | 106.44 | 13.79 | 106.77 | 21.29 |
| GILW01_3143 | 105.71 | 7.68 | 106.02 | 11.36 | 106.21 | 13.79 | 106.50 | 21.29 |
| GILW01_3138D | 105.70 | 7.68 | 106.01 | 11.36 | 106.19 | 13.79 | 106.47 | 21.29 |
| GILW01_3138E | 105.67 | 7.68 | 105.97 | 11.36 | 106.13 | 13.79 | 106.30 | 21.29 |
| GILW01_3128 | 105.67 | 7.68 | 105.97 | 11.36 | 106.14 | 13.79 | 106.31 | 21.29 |
| GILW01_2886A | 104.59 | 7.80 | 104.84 | 11.50 | 104.99 | 14.00 | 105.24 | 21.65 |
| GILW01_2886B | 104.59 | 8.87 | 104.84 | 12.92 | 104.99 | 15.91 | 105.24 | 24.77 |
| GILW01_2765i | 103.76 | 8.87 | 103.98 | 12.92 | 104.12 | 15.91 | 104.47 | 24.76 |
| GILW01_2644 | 103.11 | 8.87 | 103.33 | 12.92 | 103.48 | 15.91 | 103.82 | 24.76 |
| GILW01_2520i | 102.56 | 8.96 | 102.79 | 13.03 | 102.94 | 16.07 | 103.39 | 24.97 |
| GILW01_2396 | 102.10 | 8.96 | 102.30 | 13.03 | 102.40 | 16.07 | 102.75 | 24.96 |
| GILW01_2310i | 101.82 | 9.03 | 101.98 | 13.11 | 102.07 | 16.18 | 102.25 | 25.09 |
| GILW01_2210i | 101.50 | 9.02 | 101.64 | 13.11 | 101.73 | 16.17 | 101.86 | 25.08 |
| GILW01_2110A | 101.12 | 9.02 | 101.22 | 13.11 | 101.25 | 16.17 | 101.37 | 25.09 |
| GILW01_2110B | 101.12 | 9.99 | 101.22 | 14.50 | 101.25 | 17.92 | 101.37 | 27.70 |
| GILW01_1815 | 99.67 | 10.10 | 99.80 | 14.62 | 99.91 | 17.98 | 100.25 | 27.65 |
| GILW01_1683i | 99.24 | 10.14 | 99.54 | 14.62 | 99.77 | 17.94 | 100.22 | 27.59 |
| GILW01_1551D | 98.74 | 10.13 | 99.23 | 14.60 | 99.53 | 17.90 | 99.97 | 27.57 |
| GILW01_1551E | 98.25 | 10.13 | 98.44 | 14.60 | 98.56 | 17.90 | 98.84 | 27.57 |
| GILW01_1526i | 97.99 | 10.14 | 98.10 | 14.61 | 98.17 | 17.92 | 98.33 | 27.58 |

| ISIS Node | Q20 Max Stage (mAOD) | Q20 Max Flow (m3/s) | Q100 Max Stage (mAOD) | Q100 Max Flow (m3/s) | Q100 +20% Max Stage (mAOD) | Q100 +20% Max Flow (m3/s) | Q1000 Max Stage (mAOD) | Q1000 Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|
| GILW01_1504i | 97.80 | 10.14 | 97.90 | 14.61 | 97.96 | 17.92 | 98.10 | 27.58 |
| GILW01_1483i | 97.63 | 10.14 | 97.72 | 14.61 | 97.77 | 17.91 | 97.90 | 27.58 |
| GILW01_1418i | 97.15 | 10.14 | 97.22 | 14.60 | 97.27 | 17.92 | 97.37 | 27.59 |
| GILW01_1358i | 96.72 | 10.14 | 96.78 | 14.60 | 96.81 | 17.92 | 96.90 | 27.59 |
| GILW01_1293 | 96.30 | 10.14 | 96.36 | 14.60 | 96.41 | 17.93 | 96.52 | 27.59 |
| GILW01_1250i | 96.11 | 10.16 | 96.21 | 14.62 | 96.27 | 17.95 | 96.40 | 27.62 |
| GILW01_1207i | 96.02 | 10.15 | 96.14 | 14.62 | 96.21 | 17.95 | 96.34 | 27.62 |
| GILW01_1164i | 95.99 | 10.15 | 96.11 | 14.62 | 96.17 | 17.94 | 96.30 | 27.61 |
| GILW01_1121i | 95.97 | 10.14 | 96.09 | 14.62 | 96.15 | 17.94 | 96.26 | 27.61 |
| GILW01_1078 | 95.81 | 10.14 | 95.95 | 14.62 | 96.01 | 17.94 | 96.12 | 27.61 |
| GILW01_0836 | 94.48 | 10.15 | 94.55 | 14.61 | 94.60 | 17.93 | 94.70 | 27.60 |
| GILW01_0746i | 93.91 | 10.15 | 94.04 | 14.61 | 94.11 | 18.04 | 94.24 | 27.60 |
| GILW01_0656i | 93.56 | 10.14 | 93.81 | 14.60 | 93.94 | 18.54 | 94.06 | 27.60 |
| GILW01_0576 | 93.15 | 10.14 | 93.39 | 14.60 | 93.57 | 18.92 | 93.73 | 27.60 |
| GILW01_0476i | 92.62 | 10.14 | 92.84 | 14.60 | 92.97 | 19.08 | 93.15 | 27.59 |
| GILW01_0386i | 92.27 | 10.14 | 92.48 | 14.60 | 92.63 | 18.81 | 92.90 | 27.57 |
| GILW01_0296 | 91.46 | 10.14 | 91.64 | 14.59 | 91.76 | 18.35 | 92.02 | 27.58 |
| GILW01_0216i | 90.43 | 10.14 | 90.60 | 14.59 | 90.72 | 18.20 | 91.00 | 27.58 |
| GILW01_0136i | 89.41 | 10.14 | 89.58 | 14.59 | 89.70 | 18.17 | 89.98 | 27.58 |
| GILW01_0068i | 88.53 | 10.14 | 88.70 | 14.59 | 88.82 | 18.18 | 89.09 | 27.58 |
| GILW01_0000 | 87.68 | 10.14 | 87.85 | 14.59 | 87.98 | 18.20 | 88.25 | 27.58 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| Gilwiskaw | 117.66 | 7.41 | 117.66 | 7.41 | 117.77 | 8.89 | 117.77 | 8.89 | 117.90 | 11.05 |
| Trib1_ashby | 114.08 | 4.25 | 114.41 | 4.25 | 114.52 | 5.11 | 114.19 | 5.11 | 114.39 | 6.91 |
| Trib2_pack | 104.50 | 2.02 | 104.43 | 2.02 | 104.55 | 2.43 | 104.48 | 2.43 | 104.54 | 2.95 |
| Trib3_pack | 101.10 | 1.50 | 101.05 | 1.50 | 101.14 | 1.80 | 101.11 | 1.80 | 101.16 | 2.52 |
| Lat1 | 116.58 | 0.89 | 116.58 | 0.89 | 116.64 | 1.06 | 116.64 | 1.06 | 116.71 | 1.17 |
| Lat2 | -9999.99 | 0.87 | -9999.99 | 0.87 | -9999.99 | 1.04 | -9999.99 | 1.04 | -9999.99 | 1.15 |
| Lat2a | 107.00 | 0.16 | 106.82 | 0.16 | 107.02 | 0.19 | 106.83 | 0.19 | 106.85 | 0.21 |
| Lat2b | 105.56 | 0.71 | 105.42 | 0.71 | 105.56 | 0.85 | 105.42 | 0.85 | 105.42 | 0.93 |
| Lat3 | -9999.99 | 0.38 | -9999.99 | 0.38 | -9999.99 | 0.45 | -9999.99 | 0.45 | -9999.99 | 0.58 |
| Lat3a | 103.03 | 0.22 | 102.97 | 0.22 | 103.08 | 0.27 | 103.02 | 0.27 | 103.08 | 0.34 |
| Lat3b | 102.03 | 0.15 | 101.96 | 0.15 | 102.08 | 0.19 | 102.02 | 0.19 | 102.08 | 0.24 |
| Lat4 | -9999.99 | 0.46 | -9999.99 | 0.46 | -9999.99 | 0.55 | -9999.99 | 0.55 | -9999.99 | 0.71 |
| Lat4a | 101.10 | 0.27 | 101.05 | 0.27 | 101.14 | 0.33 | 101.11 | 0.33 | 101.16 | 0.42 |
| Lat4b | 99.66 | 0.12 | 99.63 | 0.12 | 99.69 | 0.15 | 99.66 | 0.15 | 99.72 | 0.19 |
| Lat4c | 98.23 | 0.02 | 98.18 | 0.02 | 98.28 | 0.03 | 98.24 | 0.03 | 98.32 | 0.04 |
| Lat4d | 96.29 | 0.04 | 96.28 | 0.04 | 96.31 | 0.05 | 96.30 | 0.05 | 96.32 | 0.06 |
| TRIB01_0360 | 114.08 | 4.25 | 114.41 | 4.25 | 114.52 | 5.11 | 114.19 | 5.11 | 114.39 | 6.91 |
| TRIB01_0340D | 113.98 | 4.26 | 114.39 | 4.25 | 114.49 | 5.10 | 114.08 | 5.11 | 114.26 | 6.91 |
| TRIB01_0340E | 113.98 | 4.26 | 114.39 | 4.25 | 114.49 | 5.10 | 114.08 | 5.11 | 114.26 | 6.91 |
| TRIB01_0310i | 113.86 | 4.25 | 114.38 | 4.26 | 114.48 | 5.09 | 113.98 | 5.11 | 114.17 | 6.90 |
| TRIB01_0280D | 113.78 | 4.25 | 114.38 | 4.38 | 114.48 | 5.09 | 113.91 | 5.11 | 114.12 | 6.92 |
| TRIB01_0280E | 113.65 | 4.25 | 114.35 | 4.38 | 114.44 | 5.09 | 113.78 | 5.11 | 114.00 | 6.92 |
| TRIB01_0268 | 113.57 | 4.29 | 114.34 | 4.29 | 114.44 | 5.12 | 113.72 | 5.09 | 114.00 | 6.90 |
| TRIB01_0225i | 113.47 | 4.29 | 114.34 | 4.47 | 114.42 | 5.14 | 113.61 | 5.13 | 114.00 | 6.89 |
| TRIB01_0182 | 113.42 | 4.41 | 114.32 | 4.42 | 114.40 | 5.20 | 113.53 | 5.10 | 114.00 | 6.92 |
| TRIB01_0182R | -9999.99 | 3.41 | -9999.99 | 17.08 | -9999.99 | 18.14 | -9999.99 | 3.71 | -9999.99 | 12.18 |
| TRIB01_0182L | -9999.99 | 1.94 | -9999.99 | 16.01 | -9999.99 | 17.04 | -9999.99 | 1.78 | -9999.99 | 11.39 |
| TRIB01_0145i | 113.45 | 3.57 | 113.09 | 3.17 | 113.10 | 3.45 | 113.55 | 4.11 | 113.62 | 6.02 |
| TRIB01_0145R | -9999.99 | 5.75 | -9999.99 | 4.09 | -9999.99 | 3.87 | -9999.99 | 4.56 | -9999.99 | 6.71 |
| TRIB01_0145L | -9999.99 | 3.25 | -9999.99 | 1.85 | -9999.99 | 1.94 | -9999.99 | 2.75 | -9999.99 | 4.38 |
| TRIB01_0108 | 113.45 | 3.46 | 113.55 | 32.55 | 113.64 | 33.65 | 113.57 | 4.64 | 113.63 | 24.51 |
| TRIB01_0108R | -9999.99 | 3.55 | -9999.99 | 5.24 | -9999.99 | 5.46 | -9999.99 | 3.90 | -9999.99 | 5.35 |
| TRIB01_0108L | -9999.99 | 1.91 | -9999.99 | 0.40 | -9999.99 | 2.46 | -9999.99 | 1.12 | -9999.99 | 3.64 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| TRIB01_0083i | 113.43 | 5.12 | 113.50 | 28.04 | 113.55 | 29.29 | 113.53 | 6.81 | 113.60 | 21.57 |
| TRIB01_0083R | -9999.99 | 3.65 | -9999.99 | 2.69 | -9999.99 | 5.01 | -9999.99 | 5.53 | -9999.99 | 4.00 |
| TRIB01_0083L | -9999.99 | 0.66 | -9999.99 | 0.42 | -9999.99 | 2.86 | -9999.99 | 1.21 | -9999.99 | 0.45 |
| TRIB01_0057i | 113.41 | 8.10 | 113.51 | 30.77 | 113.57 | 32.42 | 113.53 | 9.75 | 113.58 | 23.61 |
| TRIB01_0057R | -9999.99 | 7.80 | -9999.99 | 3.83 | -9999.99 | 3.63 | -9999.99 | 9.43 | -9999.99 | 9.95 |
| TRIB01_0057L | -9999.99 | 3.36 | -9999.99 | 0.77 | -9999.99 | 0.77 | -9999.99 | 3.46 | -9999.99 | 3.80 |
| TRIB01_0032 | 113.41 | 9.31 | 113.48 | 34.35 | 113.53 | 35.93 | 113.53 | 12.46 | 113.59 | 26.53 |
| TRIB01_0032R | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| TRIB01_0032L | -9999.99 | 1.26 | -9999.99 | 1.09 | -9999.99 | 1.33 | -9999.99 | 1.18 | -9999.99 | 1.39 |
| TRIB01_0000H | 113.40 | 35.07 | 113.58 | 50.14 | 113.64 | 53.17 | 113.53 | 38.18 | 113.60 | 40.24 |
| TRIB01_0000I | 113.38 | 35.07 | 113.55 | 50.14 | 113.60 | 53.17 | 113.52 | 38.18 | 113.60 | 40.24 |
| DRAIN_4910R | 116.58 | 0.00 | 116.58 | 0.00 | 116.64 | 0.00 | 116.64 | 0.00 | 116.71 | 0.00 |
| DRAIN_4896R | 116.58 | 0.00 | 116.58 | 0.00 | 116.64 | 0.00 | 116.64 | 0.00 | 116.71 | 0.00 |
| DRAIN_4882R | 116.58 | 0.22 | 116.58 | 0.22 | 116.64 | 0.62 | 116.64 | 0.62 | 116.71 | 1.30 |
| DRAIN_4869R | 116.58 | 0.14 | 116.58 | 0.14 | 116.64 | 0.40 | 116.64 | 0.40 | 116.71 | 0.86 |
| DRAIN_0533 | 116.58 | 0.91 | 116.58 | 0.91 | 116.64 | 1.66 | 116.64 | 1.66 | 116.71 | 3.00 |
| DRAIN_0503 | 116.18 | 0.91 | 116.18 | 0.91 | 116.26 | 1.66 | 116.26 | 1.66 | 116.33 | 3.00 |
| DRAIN_0488i | 116.02 | 0.91 | 116.02 | 0.91 | 116.08 | 1.66 | 116.08 | 1.66 | 116.15 | 3.00 |
| DRAIN_0473H | 115.84 | 0.91 | 115.84 | 0.91 | 115.89 | 1.66 | 115.89 | 1.66 | 115.94 | 3.00 |
| DRAIN_0473I | 115.84 | 0.91 | 115.84 | 0.91 | 115.88 | 1.66 | 115.88 | 1.66 | 115.93 | 3.00 |
| DRAIN_0458i | 115.48 | 0.91 | 115.48 | 0.91 | 115.53 | 1.66 | 115.53 | 1.66 | 115.59 | 3.00 |
| DRAIN_0443 | 115.22 | 0.91 | 115.22 | 0.91 | 115.28 | 1.66 | 115.28 | 1.66 | 115.37 | 2.99 |
| DRAIN_0425i | 115.15 | 0.91 | 115.15 | 0.91 | 115.21 | 1.66 | 115.21 | 1.66 | 115.28 | 3.00 |
| DRAIN_0408 | 115.02 | 0.91 | 115.02 | 0.91 | 115.07 | 1.66 | 115.07 | 1.66 | 115.18 | 2.99 |
| DRAIN_0378 | 114.83 | 0.91 | 114.83 | 0.91 | 114.92 | 1.66 | 114.92 | 1.64 | 115.12 | 3.10 |
| DRAIN_0336 | 114.15 | 0.91 | 114.15 | 0.92 | 114.36 | 1.64 | 114.36 | 1.66 | 114.65 | 3.13 |
| DRAIN_0292 | 113.49 | 0.91 | 113.60 | 0.92 | 113.65 | 1.64 | 113.60 | 1.66 | 113.69 | 3.22 |
| DRAIN_0292R | -9999.99 | 2.07 | -9999.99 | 3.58 | -9999.99 | 4.08 | -9999.99 | 3.51 | -9999.99 | 4.00 |
| DRAIN_0292L | -9999.99 | 2.60 | -9999.99 | 1.61 | -9999.99 | 1.69 | -9999.99 | 2.94 | -9999.99 | 4.14 |
| DRAIN_0252i | 113.39 | 0.91 | 113.48 | 0.92 | 113.53 | 1.22 | 113.47 | 1.21 | 113.52 | 1.37 |
| DRAIN_0252R | -9999.99 | 3.02 | -9999.99 | 3.09 | -9999.99 | 3.21 | -9999.99 | 3.16 | -9999.99 | 3.40 |
| DRAIN_0252L | -9999.99 | 3.11 | -9999.99 | 3.45 | -9999.99 | 3.38 | -9999.99 | 3.41 | -9999.99 | 3.31 |
| DRAIN_0212 | 113.50 | 0.88 | 113.62 | 0.85 | 113.67 | 1.02 | 113.61 | 1.01 | 113.68 | 1.01 |

| ISIS Node | Option 1 - Q100 Max Stage (mAOD) | Option 1 - Q100 Max Flow (m3/s) | Option 2 - Q100 Max Stage (mAOD) | Option 2 - Q100 Max Flow (m3/s) | Option 1 - Q100 +CC Max Stage (mAOD) | Option 1 - Q100 +CC Max Flow (m3/s) | Option 2 - Q100 + CC Max Stage (mAOD) | Option 2 - Q100 + CC Max Flow (m3/s) | Option 2 - Q100 + UD + Max Stage (mAOD) | Option 2 - Q100 + UD + Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| DRAIN_0212R | -9999.99 | 3.16 | -9999.99 | 3.08 | -9999.99 | 3.48 | -9999.99 | 3.37 | -9999.99 | 3.67 |
| DRAIN_0212L | -9999.99 | 1.40 | -9999.99 | 1.04 | -9999.99 | 0.94 | -9999.99 | 1.68 | -9999.99 | 2.28 |
| DRAIN_0154 | 113.52 | 7.36 | 113.63 | 7.44 | 113.68 | 7.71 | 113.63 | 7.08 | 113.70 | 8.02 |
| DRAIN_0154R | -9999.99 | 1.73 | -9999.99 | 1.61 | -9999.99 | 1.91 | -9999.99 | 1.75 | -9999.99 | 1.91 |
| DRAIN_0154L | -9999.99 | 3.04 | -9999.99 | 3.01 | -9999.99 | 2.98 | -9999.99 | 2.99 | -9999.99 | 3.09 |
| DRAIN_0103 | 113.59 | 3.61 | 113.70 | 3.68 | 113.75 | 3.89 | 113.71 | 3.55 | 113.79 | 4.09 |
| DRAIN_0103R | -9999.99 | 1.24 | -9999.99 | 1.18 | -9999.99 | 1.07 | -9999.99 | 1.04 | -9999.99 | 1.24 |
| DRAIN_0103L | -9999.99 | 0.66 | -9999.99 | 0.80 | -9999.99 | 0.77 | -9999.99 | 0.78 | -9999.99 | 0.80 |
| DRAIN_0052 | 113.45 | 14.76 | 113.56 | 14.84 | 113.61 | 15.03 | 113.55 | 15.89 | 113.61 | 16.93 |
| DRAIN_0052R | -9999.99 | 0.93 | -9999.99 | 0.72 | -9999.99 | 0.46 | -9999.99 | 0.40 | -9999.99 | 0.69 |
| DRAIN_0052L | -9999.99 | 0.42 | -9999.99 | 0.43 | -9999.99 | 0.40 | -9999.99 | 0.39 | -9999.99 | 0.51 |
| DRAIN_0026 | 113.40 | 25.75 | 113.48 | 28.99 | 113.53 | 30.21 | 113.50 | 28.96 | 113.55 | 29.61 |
| DRAIN_0026R | -9999.99 | 0.75 | -9999.99 | 0.71 | -9999.99 | 0.73 | -9999.99 | 0.66 | -9999.99 | 9.64 |
| DRAIN_0026L | -9999.99 | 13.85 | -9999.99 | 10.37 | -9999.99 | 10.05 | -9999.99 | 14.90 | -9999.99 | 19.66 |
| DRAIN_0000 | 113.43 | 23.07 | 113.51 | 39.96 | 113.55 | 40.79 | 113.51 | 39.99 | 113.57 | 76.43 |
| GILW01_5100 | 117.66 | 7.41 | 117.66 | 7.41 | 117.77 | 8.89 | 117.77 | 8.89 | 117.90 | 11.05 |
| GILW01_5086i | 117.64 | 7.41 | 117.64 | 7.41 | 117.75 | 8.89 | 117.75 | 8.89 | 117.88 | 11.05 |
| GILW01_5073 | 117.63 | 7.41 | 117.63 | 7.41 | 117.74 | 8.89 | 117.74 | 8.89 | 117.88 | 11.05 |
| GILW01_5053 | 117.59 | 7.41 | 117.59 | 7.41 | 117.70 | 8.89 | 117.70 | 8.89 | 117.83 | 11.04 |
| GILW01_5031 | 117.43 | 7.41 | 117.43 | 7.41 | 117.53 | 8.89 | 117.53 | 8.89 | 117.65 | 11.04 |
| GILW01_5013 | 117.42 | 7.41 | 117.42 | 7.41 | 117.52 | 8.89 | 117.52 | 8.89 | 117.64 | 11.04 |
| GILW01_4995 | 117.36 | 7.41 | 117.36 | 7.41 | 117.46 | 8.89 | 117.46 | 8.89 | 117.57 | 11.04 |
| GILW01_4968 | 117.20 | 7.41 | 117.20 | 7.41 | 117.28 | 8.89 | 117.28 | 8.89 | 117.37 | 11.04 |
| GILW01_4950 | 117.16 | 7.41 | 117.16 | 7.41 | 117.24 | 8.89 | 117.24 | 8.89 | 117.33 | 11.04 |
| GILW01_4925 | 117.13 | 7.41 | 117.13 | 7.41 | 117.20 | 8.89 | 117.20 | 8.89 | 117.29 | 11.04 |
| GILW01_4917i | 117.12 | 7.41 | 117.12 | 7.41 | 117.19 | 8.89 | 117.19 | 8.89 | 117.27 | 11.04 |
| GILW01_4910 | 117.10 | 7.41 | 117.10 | 7.41 | 117.17 | 8.89 | 117.17 | 8.89 | 117.24 | 11.04 |
| GILW01_4910R | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_4896 | 117.08 | 7.41 | 117.08 | 7.41 | 117.14 | 8.89 | 117.14 | 8.89 | 117.21 | 11.04 |
| GILW01_4896R | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_4882 | 117.07 | 7.41 | 117.07 | 7.41 | 117.14 | 8.89 | 117.14 | 8.89 | 117.20 | 11.04 |
| GILW01_4882R | -9999.99 | 0.22 | -9999.99 | 0.22 | -9999.99 | 0.62 | -9999.99 | 0.62 | -9999.99 | 1.30 |
| GILW01_4869 | 117.00 | 7.19 | 117.00 | 7.19 | 117.07 | 8.27 | 117.07 | 8.27 | 117.14 | 9.74 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| GILW01_4869R | -9999.99 | 0.14 | -9999.99 | 0.14 | -9999.99 | 0.40 | -9999.99 | 0.40 | -9999.99 | 0.86 |
| GILW01_4842 | 116.74 | 7.05 | 116.74 | 7.05 | 116.82 | 7.87 | 116.82 | 7.87 | 116.89 | 8.88 |
| GILW01_4826 | 116.78 | 7.05 | 116.78 | 7.05 | 116.86 | 7.87 | 116.86 | 7.87 | 116.95 | 8.88 |
| GILW01_4820i | 116.75 | 7.05 | 116.75 | 7.05 | 116.83 | 7.87 | 116.83 | 7.87 | 116.92 | 8.88 |
| GILW01_4814 | 116.52 | 7.05 | 116.52 | 7.05 | 116.59 | 7.87 | 116.59 | 7.87 | 116.66 | 8.88 |
| GILW01_4805i | 116.39 | 7.05 | 116.39 | 7.05 | 116.46 | 7.87 | 116.46 | 7.87 | 116.53 | 8.88 |
| GILW01_4795 | 116.24 | 7.05 | 116.24 | 7.05 | 116.31 | 7.87 | 116.31 | 7.87 | 116.39 | 8.87 |
| GILW01_4786i | 116.07 | 7.05 | 116.07 | 7.05 | 116.16 | 7.87 | 116.16 | 7.87 | 116.25 | 8.87 |
| GILW01_4777H | 115.90 | 0.00 | 115.90 | 0.00 | 116.01 | 0.00 | 116.01 | 0.00 | 116.12 | 0.00 |
| GILW01_4777L | 115.90 | 7.05 | 115.90 | 7.05 | 116.01 | 7.87 | 116.01 | 7.87 | 116.12 | 8.87 |
| GILW01_4777C | 115.90 | 7.05 | 115.90 | 7.05 | 116.01 | 7.87 | 116.01 | 7.87 | 116.12 | 8.87 |
| GILW01_4777I | 115.77 | 0.00 | 115.77 | 0.00 | 115.84 | 0.00 | 115.84 | 0.00 | 115.91 | 0.00 |
| GILW01_4771C | 115.77 | 7.05 | 115.77 | 7.05 | 115.84 | 7.87 | 115.84 | 7.87 | 115.91 | 8.87 |
| GILW01_4771M | 115.77 | 7.05 | 115.77 | 7.05 | 115.84 | 7.87 | 115.84 | 7.87 | 115.91 | 8.87 |
| GILW01_4759i | 115.56 | 7.05 | 115.56 | 7.05 | 115.62 | 7.87 | 115.62 | 7.87 | 115.69 | 8.87 |
| GILW01_4747i | 115.31 | 7.05 | 115.31 | 7.05 | 115.38 | 7.87 | 115.38 | 7.87 | 115.45 | 8.87 |
| GILW01_4735H | 115.00 | 7.05 | 115.00 | 7.05 | 115.06 | 7.87 | 115.06 | 7.87 | 115.13 | 8.87 |
| GILW01_4735I | 114.91 | 7.05 | 114.91 | 7.05 | 114.97 | 7.87 | 114.96 | 7.87 | 115.03 | 8.87 |
| GILW01_4713i | 113.92 | 7.05 | 113.92 | 7.05 | 113.97 | 7.87 | 113.99 | 7.87 | 114.06 | 8.87 |
| GILW01_4692 | 113.42 | 7.05 | 113.55 | 7.05 | 113.60 | 7.87 | 113.56 | 7.87 | 113.62 | 8.86 |
| GILW01_4667i | 113.41 | 7.05 | 113.53 | 7.05 | 113.58 | 7.87 | 113.52 | 7.85 | 113.57 | 8.89 |
| GILW01_4642 | 113.41 | 7.05 | 113.53 | 7.04 | 113.57 | 7.86 | 113.50 | 7.87 | 113.55 | 8.83 |
| GILW01_4642R | -9999.99 | 3.07 | -9999.99 | 9.16 | -9999.99 | 10.29 | -9999.99 | 5.27 | -9999.99 | 5.37 |
| GILW01_4615i | 113.41 | 6.50 | 113.52 | 6.39 | 113.58 | 6.89 | 113.51 | 6.73 | 113.57 | 7.22 |
| GILW01_4615R | -9999.99 | 3.55 | -9999.99 | 4.36 | -9999.99 | 6.54 | -9999.99 | 6.76 | -9999.99 | 7.21 |
| GILW01_4587i | 113.41 | 6.08 | 113.52 | 5.98 | 113.56 | 6.35 | 113.54 | 7.08 | 113.56 | 7.09 |
| GILW01_4587R | -9999.99 | 1.04 | -9999.99 | 0.47 | -9999.99 | 0.73 | -9999.99 | 1.10 | -9999.99 | 0.20 |
| GILW01_4587L | -9999.99 | 9.79 | -9999.99 | 9.41 | -9999.99 | 10.05 | -9999.99 | 10.79 | -9999.99 | 11.51 |
| GILW01_4560 | 113.42 | 5.53 | 113.50 | 5.41 | 113.55 | 5.65 | 113.53 | 5.51 | 113.58 | 7.96 |
| GILW01_4560R | -9999.99 | 8.85 | -9999.99 | 5.10 | -9999.99 | 8.00 | -9999.99 | 10.96 | -9999.99 | 12.53 |
| GILW01_4560L | -9999.99 | 11.22 | -9999.99 | 9.39 | -9999.99 | 10.50 | -9999.99 | 13.09 | -9999.99 | 14.65 |
| GILW01_4504 | 113.42 | 5.34 | 113.56 | 5.17 | 113.61 | 5.43 | 113.53 | 5.32 | 113.61 | 5.41 |
| GILW01_4504R | -9999.99 | 0.94 | -9999.99 | 0.85 | -9999.99 | 0.92 | -9999.99 | 0.91 | -9999.99 | 0.94 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| GILW01_4504L | -9999.99 | 0.00 | -9999.99 | 0.05 | -9999.99 | 0.00 | -9999.99 | 0.02 | -9999.99 | 0.00 |
| GILW01_4475A | 113.38 | 22.07 | 113.55 | 18.71 | 113.60 | 17.60 | 113.52 | 21.26 | 113.60 | 22.26 |
| GILW01_4475B | 113.38 | 53.38 | 113.55 | 52.95 | 113.60 | 55.02 | 113.52 | 56.47 | 113.60 | 61.80 |
| GILW01_4475R | -9999.99 | 0.51 | -9999.99 | 0.43 | -9999.99 | 0.60 | -9999.99 | 0.56 | -9999.99 | 0.64 |
| GILW01_4475L | -9999.99 | 0.33 | -9999.99 | 0.43 | -9999.99 | 0.48 | -9999.99 | 0.41 | -9999.99 | 0.59 |
| GILW01_4446 | 113.47 | 81.71 | 113.37 | 72.35 | 113.40 | 77.09 | 113.54 | 89.98 | 113.61 | 98.46 |
| GILW01_4446R | -9999.99 | 11.94 | -9999.99 | 13.36 | -9999.99 | 13.08 | -9999.99 | 22.69 | -9999.99 | 19.32 |
| GILW01_4446L | -9999.99 | 3.89 | -9999.99 | 10.38 | -9999.99 | 11.68 | -9999.99 | 10.47 | -9999.99 | 10.82 |
| GILW01_4398i | 113.40 | 76.01 | 113.43 | 60.10 | 113.48 | 59.34 | 113.50 | 82.94 | 113.56 | 84.32 |
| GILW01_4398R | -9999.99 | 17.40 | -9999.99 | 14.78 | -9999.99 | 15.29 | -9999.99 | 24.17 | -9999.99 | 27.87 |
| GILW01_4398L | -9999.99 | 7.28 | -9999.99 | 10.76 | -9999.99 | 10.96 | -9999.99 | 14.10 | -9999.99 | 17.35 |
| GILW01_4351A | 113.43 | 58.84 | 113.51 | 47.35 | 113.55 | 46.14 | 113.51 | 65.79 | 113.57 | 63.07 |
| GILW01_4351B | 113.43 | 77.50 | 113.51 | 66.06 | 113.55 | 66.96 | 113.51 | 95.67 | 113.57 | 128.00 |
| GILW01_4351R | -9999.99 | 2.92 | -9999.99 | 4.99 | -9999.99 | 4.93 | -9999.99 | 7.87 | -9999.99 | 10.70 |
| GILW01_4351L | -9999.99 | 1.20 | -9999.99 | 0.99 | -9999.99 | 1.19 | -9999.99 | 1.04 | -9999.99 | 7.73 |
| GILW01_4327i | 113.41 | 81.38 | 113.49 | 69.42 | 113.54 | 72.39 | 113.50 | 97.84 | 113.61 | 115.42 |
| GILW01_4327R | -9999.99 | 8.48 | -9999.99 | 28.28 | -9999.99 | 36.03 | -9999.99 | 8.65 | -9999.99 | 61.91 |
| GILW01_4327L | -9999.99 | 1.14 | -9999.99 | 25.04 | -9999.99 | 33.46 | -9999.99 | 0.98 | -9999.99 | 60.43 |
| GILW01_4302 | 113.43 | 77.70 | 113.58 | 74.84 | 113.65 | 75.97 | 113.51 | 104.09 | 113.78 | 84.50 |
| GILW01_4302R | -9999.99 | 3.53 | -9999.99 | 32.19 | -9999.99 | 35.82 | -9999.99 | 31.07 | -9999.99 | 51.95 |
| GILW01_4302L | -9999.99 | 5.24 | -9999.99 | 29.84 | -9999.99 | 32.73 | -9999.99 | 29.78 | -9999.99 | 49.02 |
| GILW01_4285i | 113.43 | 72.46 | 113.56 | 59.88 | 113.58 | 59.89 | 113.64 | 85.15 | 113.67 | 77.55 |
| GILW01_4285R | -9999.99 | 1.55 | -9999.99 | 35.03 | -9999.99 | 32.40 | -9999.99 | 27.28 | -9999.99 | 30.52 |
| GILW01_4285L | -9999.99 | 4.36 | -9999.99 | 33.92 | -9999.99 | 31.33 | -9999.99 | 25.48 | -9999.99 | 24.56 |
| GILW01_4267i | 113.43 | 69.46 | 113.57 | 57.89 | 113.57 | 49.72 | 113.61 | 81.72 | 113.54 | 77.28 |
| GILW01_4267R | -9999.99 | 3.16 | -9999.99 | 28.20 | -9999.99 | 28.69 | -9999.99 | 39.87 | -9999.99 | 25.35 |
| GILW01_4267L | -9999.99 | 7.51 | -9999.99 | 27.00 | -9999.99 | 27.34 | -9999.99 | 39.26 | -9999.99 | 25.85 |
| GILW01_4249 | 113.45 | 66.95 | 113.51 | 46.45 | 113.55 | 41.64 | 113.62 | 65.57 | 113.62 | 63.78 |
| GILW01_4249R | -9999.99 | 26.20 | -9999.99 | 28.20 | -9999.99 | 19.15 | -9999.99 | 34.41 | -9999.99 | 33.96 |
| GILW01_4249L | -9999.99 | 21.94 | -9999.99 | 26.81 | -9999.99 | 18.31 | -9999.99 | 33.18 | -9999.99 | 32.60 |
| GILW01_4233i | 113.54 | 52.75 | 113.49 | 39.96 | 113.53 | 37.00 | 113.59 | 50.65 | 113.66 | 51.59 |
| GILW01_4233R | -9999.99 | 10.86 | -9999.99 | 4.44 | -9999.99 | 3.62 | -9999.99 | 10.85 | -9999.99 | 9.45 |
| GILW01_4233L | -9999.99 | 6.18 | -9999.99 | 1.42 | -9999.99 | 1.34 | -9999.99 | 6.00 | -9999.99 | 4.79 |

| ISIS Node | Option 1 - Q100 Max Stage (mAOD) | Option 1 - Q100 Max Flow (m3/s) | Option 2 - Q100 Max Stage (mAOD) | Option 2 - Q100 Max Flow (m3/s) | Option 1 - Q100 +CC Max Stage (mAOD) | Option 1 - Q100 +CC Max Flow (m3/s) | Option 2 - Q100 + CC Max Stage (mAOD) | Option 2 - Q100 + CC Max Flow (m3/s) | Option 2 - Q100 + UD + Max Stage (mAOD) | Option 2 - Q100 + UD + Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| GILW01_4217i | 113.51 | 46.81 | 113.61 | 34.45 | 113.69 | 32.99 | 113.64 | 44.75 | 113.82 | 45.92 |
| GILW01_4217R | -9999.99 | 5.63 | -9999.99 | 4.07 | -9999.99 | 3.73 | -9999.99 | 5.29 | -9999.99 | 5.32 |
| GILW01_4217L | -9999.99 | 1.16 | -9999.99 | 0.98 | -9999.99 | 1.17 | -9999.99 | 0.97 | -9999.99 | 1.14 |
| GILW01_4200 | 113.44 | 40.86 | 113.50 | 52.54 | 113.55 | 61.18 | 113.51 | 56.29 | 113.56 | 77.38 |
| GILW01_4200L | -9999.99 | 0.04 | -9999.99 | 0.03 | -9999.99 | 0.01 | -9999.99 | 2.43 | -9999.99 | 0.34 |
| GILW01_4193i | 113.44 | 41.07 | 113.49 | 53.64 | 113.53 | 62.31 | 113.50 | 57.16 | 113.54 | 78.23 |
| GILW01_4193L | -9999.99 | 3.53 | -9999.99 | 5.99 | -9999.99 | 6.66 | -9999.99 | 6.99 | -9999.99 | 9.30 |
| GILW01_4185 | 113.45 | 37.88 | 113.52 | 47.64 | 113.58 | 55.66 | 113.56 | 50.53 | 113.61 | 69.72 |
| GILW01_4185L | -9999.99 | 31.79 | -9999.99 | 42.69 | -9999.99 | 49.33 | -9999.99 | 54.24 | -9999.99 | 63.62 |
| GILW01_4168i | 113.50 | 6.27 | 113.61 | 4.98 | 113.69 | 6.35 | 113.65 | 7.70 | 113.77 | 8.37 |
| GILW01_4152i | 113.50 | 6.23 | 113.61 | 4.96 | 113.69 | 6.33 | 113.65 | 6.81 | 113.78 | 7.19 |
| GILW01_4097D | 109.77 | 6.19 | 109.54 | 4.96 | 109.79 | 6.32 | 109.55 | 5.01 | 109.56 | 5.05 |
| GILW01_4097E | 109.66 | 6.19 | 109.47 | 4.96 | 109.68 | 6.32 | 109.47 | 5.01 | 109.48 | 5.05 |
| GILW01_4043 | 109.50 | 6.19 | 109.30 | 4.96 | 109.52 | 6.32 | 109.31 | 4.99 | 109.32 | 5.05 |
| GILW01_3981 | 108.93 | 6.19 | 108.84 | 4.96 | 108.94 | 6.32 | 108.85 | 4.98 | 108.85 | 5.05 |
| GILW01_3934i | 108.68 | 6.19 | 108.63 | 4.96 | 108.69 | 6.32 | 108.63 | 4.98 | 108.64 | 5.05 |
| GILW01_3888 | 108.54 | 6.19 | 108.49 | 4.96 | 108.55 | 6.32 | 108.49 | 4.98 | 108.49 | 5.05 |
| GILW01_3795 | 107.87 | 6.19 | 107.82 | 4.96 | 107.87 | 6.32 | 107.82 | 4.98 | 107.83 | 5.06 |
| GILW01_3728 | 107.49 | 6.19 | 107.47 | 4.96 | 107.50 | 6.32 | 107.47 | 4.98 | 107.47 | 5.05 |
| GILW01_3647 | 107.16 | 6.19 | 107.04 | 4.96 | 107.18 | 6.32 | 107.05 | 4.98 | 107.06 | 5.05 |
| GILW01_3585D | 107.00 | 6.19 | 106.83 | 4.96 | 107.02 | 6.32 | 106.84 | 4.98 | 106.85 | 5.05 |
| GILW01_3585E | 107.00 | 6.19 | 106.82 | 4.96 | 107.02 | 6.32 | 106.83 | 4.98 | 106.85 | 5.05 |
| GILW01_3530 | 106.85 | 6.19 | 106.67 | 4.96 | 106.87 | 6.34 | 106.68 | 5.01 | 106.69 | 5.12 |
| GILW01_3516 | 106.85 | 6.19 | 106.67 | 4.96 | 106.87 | 6.34 | 106.68 | 5.01 | 106.69 | 5.12 |
| GILW01_3516H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3511D | 106.84 | 6.19 | 106.66 | 4.96 | 106.86 | 6.34 | 106.67 | 5.01 | 106.69 | 5.12 |
| GILW01_3511E | 106.81 | 6.19 | 106.65 | 4.96 | 106.83 | 6.34 | 106.66 | 5.01 | 106.67 | 5.12 |
| GILW01_3511I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3494i | 106.77 | 6.19 | 106.61 | 4.96 | 106.79 | 6.34 | 106.62 | 5.01 | 106.63 | 5.12 |
| GILW01_3477 | 106.69 | 6.19 | 106.53 | 4.96 | 106.71 | 6.34 | 106.54 | 5.01 | 106.55 | 5.12 |
| GILW01_3425 | 106.60 | 6.19 | 106.43 | 4.96 | 106.62 | 6.34 | 106.44 | 5.01 | 106.45 | 5.11 |
| GILW01_3425H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3418D | 106.59 | 6.19 | 106.42 | 4.96 | 106.61 | 6.34 | 106.43 | 5.01 | 106.44 | 5.11 |

| ISIS Node | Option 1 - Q100 Max Stage (mAOD) | Option 1 - Q100 Max Flow (m3/s) | Option 2 - Q100 Max Stage (mAOD) | Option 2 - Q100 Max Flow (m3/s) | Option 1 - Q100 +CC Max Stage (mAOD) | Option 1 - Q100 +CC Max Flow (m3/s) | Option 2 - Q100 + CC Max Stage (mAOD) | Option 2 - Q100 + CC Max Flow (m3/s) | Option 2 - Q100 + UD + Max Stage (mAOD) | Option 2 - Q100 + UD + Max Flow (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| GILW01_3418E | 106.55 | 6.19 | 106.40 | 4.96 | 106.57 | 6.34 | 106.40 | 5.01 | 106.42 | 5.11 |
| GILW01_3418I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3335 | 106.48 | 6.19 | 106.30 | 4.96 | 106.50 | 6.34 | 106.31 | 5.01 | 106.33 | 5.11 |
| GILW01_3273 | 106.33 | 6.19 | 106.16 | 4.96 | 106.36 | 6.34 | 106.16 | 5.01 | 106.18 | 5.12 |
| GILW01_3273H | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3266D | 106.31 | 6.19 | 106.14 | 4.96 | 106.33 | 6.34 | 106.15 | 5.01 | 106.16 | 5.12 |
| GILW01_3266E | 106.25 | 6.19 | 106.11 | 4.96 | 106.27 | 6.34 | 106.12 | 5.01 | 106.13 | 5.12 |
| GILW01_3266I | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 | -9999.99 | 0.00 |
| GILW01_3203 | 105.86 | 6.19 | 105.72 | 4.96 | 105.86 | 6.34 | 105.72 | 5.01 | 105.73 | 5.12 |
| GILW01_3143 | 105.60 | 6.19 | 105.46 | 4.96 | 105.60 | 6.33 | 105.46 | 5.01 | 105.46 | 5.12 |
| GILW01_3138D | 105.59 | 6.19 | 105.45 | 4.96 | 105.59 | 6.33 | 105.45 | 5.01 | 105.45 | 5.12 |
| GILW01_3138E | 105.56 | 6.19 | 105.43 | 4.96 | 105.57 | 6.33 | 105.43 | 5.01 | 105.43 | 5.12 |
| GILW01_3128 | 105.56 | 6.19 | 105.42 | 4.96 | 105.56 | 6.33 | 105.42 | 5.01 | 105.42 | 5.12 |
| GILW01_2886A | 104.50 | 6.20 | 104.43 | 5.00 | 104.55 | 6.40 | 104.48 | 5.18 | 104.54 | 5.42 |
| GILW01_2886B | 104.50 | 7.60 | 104.43 | 6.69 | 104.55 | 8.39 | 104.48 | 7.41 | 104.54 | 8.25 |
| GILW01_2765i | 103.68 | 7.59 | 103.62 | 6.68 | 103.73 | 8.38 | 103.67 | 7.41 | 103.72 | 8.24 |
| GILW01_2644 | 103.03 | 7.59 | 102.97 | 6.69 | 103.08 | 8.38 | 103.02 | 7.41 | 103.08 | 8.24 |
| GILW01_2520i | 102.48 | 7.79 | 102.42 | 6.89 | 102.54 | 8.62 | 102.47 | 7.66 | 102.54 | 8.56 |
| GILW01_2396 | 102.03 | 7.79 | 101.96 | 6.89 | 102.08 | 8.62 | 102.02 | 7.66 | 102.08 | 8.56 |
| GILW01_2310i | 101.76 | 7.92 | 101.70 | 7.03 | 101.81 | 8.78 | 101.75 | 7.83 | 101.81 | 8.78 |
| GILW01_2210i | 101.44 | 7.92 | 101.39 | 7.03 | 101.48 | 8.78 | 101.44 | 7.83 | 101.48 | 8.77 |
| GILW01_2110A | 101.10 | 7.92 | 101.05 | 7.02 | 101.14 | 8.78 | 101.11 | 7.83 | 101.16 | 8.77 |
| GILW01_2110B | 101.10 | 9.40 | 101.05 | 8.48 | 101.14 | 10.55 | 101.11 | 9.57 | 101.16 | 11.29 |
| GILW01_1815 | 99.66 | 9.62 | 99.63 | 8.72 | 99.69 | 10.82 | 99.66 | 9.84 | 99.72 | 11.64 |
| GILW01_1683i | 99.21 | 9.72 | 99.16 | 8.82 | 99.29 | 10.93 | 99.23 | 9.97 | 99.34 | 11.77 |
| GILW01_1551D | 98.69 | 9.71 | 98.59 | 8.81 | 98.83 | 10.92 | 98.72 | 9.96 | 98.92 | 11.74 |
| GILW01_1551E | 98.23 | 9.71 | 98.18 | 8.81 | 98.28 | 10.92 | 98.24 | 9.96 | 98.32 | 11.74 |
| GILW01_1526i | 97.98 | 9.73 | 97.95 | 8.83 | 98.02 | 10.94 | 97.99 | 9.98 | 98.04 | 11.77 |
| GILW01_1504i | 97.79 | 9.73 | 97.77 | 8.83 | 97.82 | 10.94 | 97.80 | 9.98 | 97.84 | 11.77 |
| GILW01_1483i | 97.62 | 9.73 | 97.60 | 8.83 | 97.65 | 10.94 | 97.63 | 9.98 | 97.67 | 11.77 |
| GILW01_1418i | 97.14 | 9.73 | 97.12 | 8.83 | 97.16 | 10.94 | 97.15 | 9.98 | 97.18 | 11.76 |
| GILW01_1358i | 96.72 | 9.73 | 96.70 | 8.83 | 96.73 | 10.94 | 96.72 | 9.98 | 96.74 | 11.76 |
| GILW01_1293 | 96.29 | 9.73 | 96.28 | 8.83 | 96.31 | 10.94 | 96.30 | 9.98 | 96.32 | 11.77 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| GILW01_1250i | 96.09 | 9.75 | 96.07 | 8.86 | 96.13 | 10.97 | 96.10 | 10.02 | 96.15 | 11.81 |
| GILW01_1207i | 96.01 | 9.75 | 95.98 | 8.86 | 96.05 | 10.97 | 96.02 | 10.02 | 96.08 | 11.81 |
| GILW01_1164i | 95.98 | 9.75 | 95.96 | 8.86 | 96.03 | 10.97 | 95.99 | 10.02 | 96.06 | 11.81 |
| GILW01_1121i | 95.96 | 9.75 | 95.94 | 8.86 | 96.01 | 10.97 | 95.97 | 10.02 | 96.04 | 11.81 |
| GILW01_1078 | 95.80 | 9.75 | 95.76 | 8.87 | 95.85 | 10.97 | 95.81 | 10.02 | 95.88 | 11.80 |
| GILW01_0836 | 94.47 | 9.75 | 94.45 | 8.86 | 94.49 | 10.96 | 94.47 | 10.01 | 94.51 | 11.79 |
| GILW01_0746i | 93.89 | 9.74 | 93.86 | 8.86 | 93.93 | 10.96 | 93.90 | 10.01 | 93.95 | 11.79 |
| GILW01_0656i | 93.53 | 9.75 | 93.48 | 8.86 | 93.61 | 10.96 | 93.55 | 10.01 | 93.65 | 11.78 |
| GILW01_0576 | 93.13 | 9.75 | 93.07 | 8.86 | 93.20 | 10.96 | 93.14 | 10.01 | 93.25 | 11.77 |
| GILW01_0476i | 92.60 | 9.75 | 92.54 | 8.86 | 92.67 | 10.96 | 92.61 | 10.01 | 92.71 | 11.77 |
| GILW01_0386i | 92.25 | 9.75 | 92.20 | 8.86 | 92.31 | 10.96 | 92.26 | 10.01 | 92.35 | 11.77 |
| GILW01_0296 | 91.45 | 9.75 | 91.41 | 8.86 | 91.50 | 10.96 | 91.46 | 10.01 | 91.53 | 11.77 |
| GILW01_0216i | 90.41 | 9.75 | 90.37 | 8.86 | 90.46 | 10.96 | 90.42 | 10.01 | 90.49 | 11.77 |
| GILW01_0136i | 89.39 | 9.75 | 89.35 | 8.86 | 89.44 | 10.96 | 89.40 | 10.01 | 89.47 | 11.77 |
| GILW01_0068i | 88.51 | 9.75 | 88.47 | 8.86 | 88.56 | 10.95 | 88.52 | 10.01 | 88.59 | 11.77 |
| GILW01_0000 | 87.67 | 9.75 | 87.63 | 8.85 | 87.72 | 10.95 | 87.68 | 10.01 | 87.75 | 11.77 |
| RESA_4642R | 113.39 | 3.07 | 113.50 | 9.16 | 113.55 | 10.29 | 113.49 | 5.27 | 113.54 | 5.37 |
| RESA_4615R | 113.39 | 3.55 | 113.50 | 4.36 | 113.55 | 6.54 | 113.49 | 6.76 | 113.54 | 7.21 |
| RESA_4587R | 113.39 | 1.04 | 113.50 | 0.47 | 113.55 | 0.73 | 113.49 | 1.10 | 113.54 | 0.20 |
| RESA_0292L | 113.39 | 2.60 | 113.50 | 1.61 | 113.55 | 1.69 | 113.49 | 2.94 | 113.54 | 4.14 |
| RESA_0252L | 113.39 | 3.11 | 113.50 | 3.45 | 113.55 | 3.38 | 113.49 | 3.41 | 113.54 | 3.31 |
| RESA_0212L | 113.39 | 1.40 | 113.50 | 1.04 | 113.55 | 0.94 | 113.49 | 1.68 | 113.54 | 2.28 |
| RESA_BSPILL | 113.39 | 2.76 | 113.50 | 3.43 | 113.55 | 4.10 | 113.49 | 3.91 | 113.54 | 4.05 |
| RESB_ASPILL | 113.38 | 2.76 | 113.48 | 3.43 | 113.52 | 4.10 | 113.46 | 3.91 | 113.53 | 4.05 |
| RESB_4560R | 113.38 | 8.85 | 113.48 | 5.10 | 113.52 | 8.00 | 113.46 | 10.96 | 113.53 | 12.53 |
| RESB_4504R | 113.38 | 0.94 | 113.48 | 0.85 | 113.52 | 0.92 | 113.46 | 0.91 | 113.53 | 0.94 |
| RESB_4475R | 113.38 | 0.51 | 113.48 | 0.43 | 113.52 | 0.60 | 113.46 | 0.56 | 113.53 | 0.64 |
| RESB_4446R | 113.38 | 11.94 | 113.48 | 13.36 | 113.52 | 13.08 | 113.46 | 22.69 | 113.53 | 19.32 |
| RESB_4398R | 113.38 | 17.40 | 113.48 | 14.78 | 113.52 | 15.29 | 113.46 | 24.17 | 113.53 | 27.87 |
| RESB_0154L | 113.38 | 3.04 | 113.48 | 3.01 | 113.52 | 2.98 | 113.46 | 2.99 | 113.53 | 3.09 |
| RESB_0103L | 113.38 | 0.66 | 113.48 | 0.80 | 113.52 | 0.77 | 113.46 | 0.78 | 113.53 | 0.80 |
| RESB_0052L | 113.38 | 0.42 | 113.48 | 0.43 | 113.52 | 0.40 | 113.46 | 0.39 | 113.53 | 0.51 |
| RESB_0026L | 113.38 | 13.85 | 113.48 | 10.37 | 113.52 | 10.05 | 113.46 | 14.90 | 113.53 | 19.66 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| RESC_0182R | 113.37 | 3.41 | 113.46 | 17.08 | 113.50 | 18.14 | 113.46 | 3.71 | 113.52 | 12.18 |
| RESC_0145R | 113.37 | 5.75 | 113.46 | 4.09 | 113.50 | 3.87 | 113.46 | 4.56 | 113.52 | 6.71 |
| RESC_0108R | 113.37 | 3.55 | 113.46 | 5.24 | 113.50 | 5.46 | 113.46 | 3.90 | 113.52 | 5.35 |
| RESC_0083R | 113.37 | 3.65 | 113.46 | 2.69 | 113.50 | 5.01 | 113.46 | 5.53 | 113.52 | 4.00 |
| RESC_0057R | 113.37 | 7.80 | 113.46 | 3.83 | 113.50 | 3.63 | 113.46 | 9.43 | 113.52 | 9.95 |
| RESC_0032R | 113.37 | 0.00 | 113.46 | 0.00 | 113.50 | 0.00 | 113.46 | 0.00 | 113.52 | 0.00 |
| RESC_4587L | 113.37 | 9.79 | 113.46 | 9.41 | 113.50 | 10.05 | 113.46 | 10.79 | 113.52 | 11.51 |
| RESC_4560L | 113.37 | 11.22 | 113.46 | 9.39 | 113.50 | 10.50 | 113.46 | 13.09 | 113.52 | 14.65 |
| RESC_4504L | 113.37 | 0.00 | 113.46 | 0.05 | 113.50 | 0.00 | 113.46 | 0.02 | 113.52 | 0.00 |
| RESD_0292R | 113.40 | 2.07 | 113.49 | 3.58 | 113.53 | 4.08 | 113.49 | 3.51 | 113.55 | 4.00 |
| RESD_0252R | 113.40 | 3.02 | 113.49 | 3.09 | 113.53 | 3.21 | 113.49 | 3.16 | 113.55 | 3.40 |
| RESD_0212R | 113.40 | 3.16 | 113.49 | 3.08 | 113.53 | 3.48 | 113.49 | 3.37 | 113.55 | 3.67 |
| RESD_0154R | 113.40 | 1.73 | 113.49 | 1.61 | 113.53 | 1.91 | 113.49 | 1.75 | 113.55 | 1.91 |
| RESD_0103R | 113.40 | 1.24 | 113.49 | 1.18 | 113.53 | 1.07 | 113.49 | 1.04 | 113.55 | 1.24 |
| RESD_0052R | 113.40 | 0.93 | 113.49 | 0.72 | 113.53 | 0.46 | 113.49 | 0.40 | 113.55 | 0.69 |
| RESD_0026R | 113.40 | 0.75 | 113.49 | 0.71 | 113.53 | 0.73 | 113.49 | 0.66 | 113.55 | 9.64 |
| RESD_4351R | 113.40 | 2.92 | 113.49 | 4.99 | 113.53 | 4.93 | 113.49 | 7.87 | 113.55 | 10.70 |
| RESD_4327R | 113.40 | 8.48 | 113.49 | 28.28 | 113.53 | 36.03 | 113.49 | 8.65 | 113.55 | 61.91 |
| RESD_ESPILL | 113.40 | 0.68 | 113.49 | 7.45 | 113.53 | 11.38 | 113.49 | 0.56 | 113.55 | 19.93 |
| RESE_DSPILL | 113.42 | 0.68 | 113.48 | 7.45 | 113.53 | 11.38 | 113.50 | 0.56 | 113.54 | 19.93 |
| RESE_4302R | 113.42 | 3.53 | 113.48 | 32.19 | 113.53 | 35.82 | 113.50 | 31.07 | 113.54 | 51.95 |
| RESE_4285R | 113.42 | 1.55 | 113.48 | 35.03 | 113.53 | 32.40 | 113.50 | 27.28 | 113.54 | 30.52 |
| RESE_4267R | 113.42 | 3.16 | 113.48 | 28.20 | 113.53 | 28.69 | 113.50 | 39.87 | 113.54 | 25.35 |
| RESE_4249R | 113.42 | 26.20 | 113.48 | 28.20 | 113.53 | 19.15 | 113.50 | 34.41 | 113.54 | 33.96 |
| RESE_4233R | 113.42 | 10.86 | 113.48 | 4.44 | 113.53 | 3.62 | 113.50 | 10.85 | 113.54 | 9.45 |
| RESE_4217R | 113.42 | 5.63 | 113.48 | 4.07 | 113.53 | 3.73 | 113.50 | 5.29 | 113.54 | 5.32 |
| RESF_0182L | 113.39 | 1.94 | 113.48 | 16.01 | 113.53 | 17.04 | 113.48 | 1.78 | 113.54 | 11.39 |
| RESF_0145L | 113.39 | 3.25 | 113.48 | 1.85 | 113.53 | 1.94 | 113.48 | 2.75 | 113.54 | 4.38 |
| RESF_0108L | 113.39 | 1.91 | 113.48 | 0.40 | 113.53 | 2.46 | 113.48 | 1.12 | 113.54 | 3.64 |
| RESF_0083L | 113.39 | 0.66 | 113.48 | 0.42 | 113.53 | 2.86 | 113.48 | 1.21 | 113.54 | 0.45 |
| RESF_0057L | 113.39 | 3.36 | 113.48 | 0.77 | 113.53 | 0.77 | 113.48 | 3.46 | 113.54 | 3.80 |
| RESF_0032L | 113.39 | 1.26 | 113.48 | 1.09 | 113.53 | 1.33 | 113.48 | 1.18 | 113.54 | 1.39 |
| RESF_4475L | 113.39 | 0.33 | 113.48 | 0.43 | 113.53 | 0.48 | 113.48 | 0.41 | 113.54 | 0.59 |

| ISIS Node | Option 1 - Q100 | | Option 2 - Q100 | | Option 1 - Q100 +CC | | Option 2 - Q100 + CC | | Option 2 - Q100 + UD + | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) | Max Stage (mAOD) | Max Flow (m3/s) |
| RESF_4446L | 113.39 | 3.89 | 113.48 | 10.38 | 113.53 | 11.68 | 113.48 | 10.47 | 113.54 | 10.82 |
| RESF_4398L | 113.39 | 7.28 | 113.48 | 10.76 | 113.53 | 10.96 | 113.48 | 14.10 | 113.54 | 17.35 |
| RESF_GSPILL | 113.39 | 1.50 | 113.48 | 1.37 | 113.53 | 1.56 | 113.48 | 1.30 | 113.54 | 1.62 |
| RESG_FSPILL | 113.41 | 1.50 | 113.50 | 1.37 | 113.54 | 1.56 | 113.50 | 1.30 | 113.56 | 1.62 |
| RESG_4351L | 113.41 | 1.20 | 113.50 | 0.99 | 113.54 | 1.19 | 113.50 | 1.04 | 113.56 | 7.73 |
| RESG_4327L | 113.41 | 1.14 | 113.50 | 25.04 | 113.54 | 33.46 | 113.50 | 0.98 | 113.56 | 60.43 |
| RESG_4302L | 113.41 | 5.24 | 113.50 | 29.84 | 113.54 | 32.73 | 113.50 | 29.78 | 113.56 | 49.02 |
| RESG_4285L | 113.41 | 4.36 | 113.50 | 33.92 | 113.54 | 31.33 | 113.50 | 25.48 | 113.56 | 24.56 |
| RESG_4267L | 113.41 | 7.51 | 113.50 | 27.00 | 113.54 | 27.34 | 113.50 | 39.26 | 113.56 | 25.85 |
| RESG_HSPILL | 113.41 | 3.13 | 113.50 | 19.40 | 113.54 | 24.08 | 113.50 | 8.04 | 113.56 | 38.48 |
| RESH_GSPILL | 113.43 | 3.13 | 113.49 | 19.40 | 113.54 | 24.08 | 113.51 | 8.04 | 113.55 | 38.48 |
| RESH_4249L | 113.43 | 21.94 | 113.49 | 26.81 | 113.54 | 18.31 | 113.51 | 33.18 | 113.55 | 32.60 |
| RESH_4233L | 113.43 | 6.18 | 113.49 | 1.42 | 113.54 | 1.34 | 113.51 | 6.00 | 113.55 | 4.79 |
| RESH_4217L | 113.43 | 1.16 | 113.49 | 0.98 | 113.54 | 1.17 | 113.51 | 0.97 | 113.55 | 1.14 |
| RESH_4200L | 113.43 | 0.04 | 113.49 | 0.03 | 113.54 | 0.01 | 113.51 | 2.43 | 113.55 | 0.34 |
| RESH_4193L | 113.43 | 3.53 | 113.49 | 5.99 | 113.54 | 6.66 | 113.51 | 6.99 | 113.55 | 9.30 |
| RESH_4185L | 113.43 | 31.79 | 113.49 | 42.69 | 113.54 | 49.33 | 113.51 | 54.24 | 113.55 | 63.62 |
| GILW01_4135H | 113.50 | 1.61 | 113.61 | 0.00 | 113.69 | 1.61 | 113.65 | 0.00 | 113.78 | 0.00 |
| GILW01_4135I | 109.81 | 1.61 | 109.61 | 0.00 | 109.84 | 1.61 | 109.61 | 0.00 | 109.63 | 0.00 |
| GILW01_4135J | 113.50 | 6.19 | 113.61 | 4.96 | 113.69 | 6.32 | 113.65 | 4.98 | 113.78 | 5.05 |
| GILW01_4135K | 109.81 | 6.19 | 109.61 | 4.96 | 109.84 | 6.32 | 109.61 | 4.98 | 109.63 | 5.05 |
| GILW01_4135A | 113.50 | 6.19 | 113.61 | 4.96 | 113.69 | 6.32 | 113.65 | 4.98 | 113.78 | 5.05 |
| GILW01_4135B | 109.81 | 6.19 | 109.61 | 4.96 | 109.84 | 6.32 | 109.61 | 4.98 | 109.63 | 5.05 |

# Appendix G Guidance Notes for Developers

# Guidance Notes for Developers

### How to Use the Strategic Flood Risk Assessment

The Strategic Flood Risk Assessment is the assessment and categorisation of flood risk on a district wide basis in accordance with PPS25. SFRAs refine information on the probability of flooding, taking other sources of flooding and the impacts of climate change into account. The SFRA provides the basis for applying the Sequential Test and the Exception Test where consideration needs to be given to the impact of the flood risk management infrastructure on the frequency, impact, speed of onset, depth and velocity of flooding within the Flood Zones considering a range of flood risk management maintenance scenarios.

A developer should consider flood risk issues at a site as early as possible. The SFRA can be used to provide an indication of the likely flood risk issues at a site from all sources of flooding. Developers should identify whether the development site has been allocated for that type of land use in the Local Development Documents. For allocated sites the SFRA can provide information on the application of the Sequential Test and where undertaken the Exception Test to see if the land use is appropriate.

### When is a Flood Risk Assessment Required?

A Flood Risk Assessment (FRA) will be required to accompany planning applications for:
- any development proposals of I hectare or greater in Flood Zone 1
- any development proposals in Medium Probability Flood Zone 2
- any development proposals in High Probability Flood Zone 3

The FRA should identify and assess the risks of all sources of flooding to and from the development, taking into account climate change and demonstrate how the risk will be managed.

A FRA will also be required where the proposed development or change of use to a more vulnerable class may be subject to other sources of flooding or where the Environment Agency, Internal Drainage Board and/or other bodies have indicated that there may be drainage problems.

### Standard Flood Risk Management Guidance for Developers

The broad aim of the Planning Policy Statement 25 is to reduce the number of people and properties within the natural and built environment at risk of flooding. To achieve this aim, planning authorities are required to ensure that flood risk is properly assessed during the initial planning stages of any development.

Responsibility for this assessment lies with developers and they must demonstrate the following:
- Whether the proposed development is likely to be affected by current or future flooding from any source.
- Whether the proposed development will increase flood risk elsewhere.
- Whether the measures proposed to deal with any flood risk are sustainable.

The developer must prove to the Local Planning Authority and the Environment Agency that the existing flood risk or flood risk associated with the proposed development can be satisfactorily managed.

The detail to be provided by a FRA will depend on where the proposed site fits within the development framework, particularly on its justification against the sequential test, described in the SFRA.

Development should follow the standard flood risk assessment approach provided by the Environment Agency and Ciria, as follows:

- National Standing Advice to Local Planning Authorities for Planning Applications - Development and Flood Risk in England' (June 2004)
- CIRIA Report C624 "Development and Flood Risk – Guidance for the Construction Industry" (2004).

The general requirements of a FRA are listed in Appendix E of PPS25 and within the Practice Guide to PPS25. Further guidance on the level of detail required for a FRA can be found in the Environment Agency's Flood Risk Assessment guidance notes available at http://www.pipernetworking.com/floodrisk/index.html

**Guidance for Development within Each Flood Zone**

An FRA should be commensurate with the risk of flooding to the proposed development. For example, where the risk of flooding of the site is negligible (Zone 1 Low Probability) there is little benefit to be gained in assessing the potential risk to life and/or property as a result of flooding. The particular requirements for FRAs within each of the flood zones delineated within PPS25 are outlined below.

<u>Flood Zone 1 Low Probability</u>

There are generally no flood risk related constraints placed upon future development within Zone 1 Low Probability according to PPS25; however it is important to recognise that if development is not carefully managed within this zone it may adversely affect the existing flooding regime.

The risks of alternative sources of flooding (e.g. groundwater, pluvial) need to be considered. The proposed development should also consider surface water runoff to ensure that there are no detrimental effects to existing development and where possible the runoff is reduced through sustainable drainage systems.

<u>Flood Zone 2 Medium Probability</u>

After the Sequential Test has been applied and the lowest risk suitable site has been chosen, PPS25 recommends that development within Flood Zone 2 should be restricted to 'essential infrastructure', 'water compatible', 'more vulnerable' or 'less vulnerable' land uses.

Where no suitable alternative sites at lower flood risk is found during the Sequential Test if 'Highly Vulnerable' development should be considered further within Flood Zone 2 it will be necessary to carry out the Exception Test.

PPS states that for the Exception Test to be passed:

1. *it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared.*
2. *the development should be on developable, previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and*
3. *a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.*

The risks of alternative sources of flooding (e.g. groundwater, pluvial) need to be considered. The proposed development should consider surface water runoff to ensure that there are no detrimental effects to existing development and where possible the runoff is reduced through sustainable drainage systems.

As part of the FRA, it will be necessary to demonstrate that the residual risk of flooding can be effectively managed and a planned evacuation route or safe haven can be provided.

Flood Zone 3a High Probability

After the Sequential Test has been applied and the lowest risk suitable site has been chosen, PPS25 recommends that development within Flood Zone 3a should be restricted to 'Less Vulnerable' and 'Water Compatible' land uses.

Where no suitable alternative sites at lower flood risk is found during the Sequential Test if 'More Vulnerable' development or 'Essential Infrastructure' should be considered further within Flood Zone 3a it will be necessary to carry out the Exception Test (see above for details).

An FRA should include the following:

- The vulnerability of the development to fluvial and/or tidal flooding as well as to flooding from other sources.
- The impact of climate change over the lifetime of the development on the flooding regime, i.e. maximum water levels, flood extents and flow paths.
- The effect of the new development on surface water runoff ensuring that there are no detrimental effects to existing development and where possible that runoff is reduced through the use of appropriate sustainable drainage systems.
- Demonstration that residual risks of flooding, after existing and proposed flood management and mitigation measures are taken into account, are acceptable.
- Demonstration that dry access can be provided to enable the safe evacuation in the event of flooding or where this is not achievable a safe haven can be provided.

Flood Zone 3b Functional Floodplain

After the Sequential Test has been applied and the lowest risk suitable site has been chosen, PPS25 recommends that development within Flood Zone 3b should be restricted to 'water compatible' land uses.

Where no suitable alternative sites at lower flood risk is found during the Sequential Test if 'Essential Infrastructure' should be considered further within Flood Zone 3b it will be necessary to carry out the Exception Test (see above for details).

An FRA should include the following:

- The vulnerability of the development to fluvial and/or tidal flooding as well as other sources, e.g. groundwater, sewer, surface water, critical infrastructure failure.
- The impact of climate change over the lifetime of the development on the flooding regime, i.e. maximum water levels, flood extents and flow paths.
- The effect of the new development on surface water runoff ensuring that there are no detrimental effects to existing development and where possible that runoff is reduced through sustainable drainage systems.
- Demonstration that residual risks of flooding, after existing and proposed flood management and mitigation measures are taken into account, are acceptable.
- Demonstration that dry access can be provided to enable the safe evacuation in the event of flooding or where this is not achievable a safe haven can be provided.

**Additional Guidance**

Undefended Floodplain

Areas at risk of flooding need to be assessed against the 1% annual exceedance probability (AEP) criteria for fluvial flooding and against the 0.5% AEP criteria for tidal flooding. The Environment Agency's hydraulic models may be made available for use by developers to determine the site's vulnerability to flooding. . The developer will need to firstly ensure that the models are fit for purpose and sufficiently detailed to provide an accurate understanding of flood risk to the site. If existing models are not available, then a developer will need to assess the extent and requirements of any modelling work that is required. Detailed hydraulic modelling will involve the following:

- Carrying out a hydrological assessment using Flood Estimation Handbook techniques and using gauging records where available.
- Constructing an in-bank model using up to date survey data including structures, e.g. bridges, weirs, culverts and sluices.
- Extending the in-bank model to include floodplains where necessary using appropriate hydraulic modelling approaches to replicate the extent, storage and conveyance of the floodplains, e.g. through extended cross sections, reservoir units or 2-D modelling.
- Calibrating or verifying the hydraulic model where hydrometric monitoring data or flood records are available.
- Carrying out sensitivity analysis to confirm modelling assumptions and assess climate change impacts.
- Mapping of flooding extents

Defended Floodplain

Development sites within a defended tidal or fluvial floodplain are at particular risk due to the risk of the defences being overtopped or breached, resulting in the rapid onset of fast flowing and deep water flooding with little or no warning.

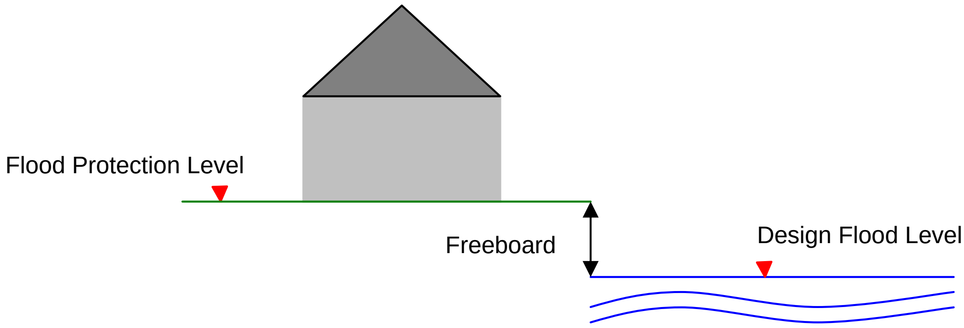
Residual risk from the breach or overtopping of defences needs to be considered as part of a FRA. Defra's[1] Flood Risk Assessment Guidance for New Development provides guidance on the level of risk related to distance and flood depth for overtopping and breaching scenarios.

The objectives of a breach analysis are as follows:
- to determine the Rapid Inundation Zone where there is a potential risk to life
- to investigate the impact of the proposed development on the flood risk to others
- to test the effectiveness of mitigation measures

Consideration of flood risk behind defences should take into consideration the standard of protection and design freeboard of the flood defence along with its condition and potential mechanisms of failure. The parameters of a breach in terms of potential location and width as well as the duration of a flood event should be agreed with the Environment Agency prior to any analysis.

Raised Floor Levels

It may be feasible to reduce the risk to a development through raising the ground level above the design flood level, as shown below:




[1] Flood Risk Assessment Guidance for New Development Phase 2: Framework and guidance for Assessing and Managing Flood Risk for New Development – Full Documentation and Tools. R&D Technical Report FD2320/TR2. Defra/Environment Agency 2005

Floor levels should be raised above the 1% AEP fluvial flood level plus an allowance for climate change assuming a 20% increase in flow over the next 100 years.

In addition, the flood protection level should include a freeboard above the design flood level. For non-residential development, e.g. commercial, the Environment Agency usually requires a freeboard of 300mm and for residential development a freeboard of 600mm.

Compensatory Storage

Where development is proposed in undefended areas of floodplain, which lie outside of the functional floodplain, the new building footprint and any ground raising will effectively reduce the flood storage capacity of the site. The potential impacts on flood risk elsewhere need to be considered. Raising existing ground levels may reduce the capacity of the floodplain to accommodate floodwater and increase the risk of flooding by either increasing the depth of flooding to existing properties at risk or by extending the floodplain to cover properties normally outside of the floodplain. Flood storage capacity can be maintained by lowering ground levels either within the curtilage of the development or elsewhere in the floodplain to provide at least the equivalent volume of storage lost to the development at a nearby location and at the same level. Compensatory storage should be provided on a level for level and volume for volume basis.

For development in a defended flood risk area, the impact on residual flood risk to other properties needs to be considered. New development behind flood defences can increase the residual risk of flooding if the flood defences are breached or overtopped by changing the conveyance of the flow paths or by displacing flood water elsewhere. If the potential impact on residual risk is unacceptable then mitigation should be provided.

**Surface Water Drainage Assessment**

Developers should demonstrate that the disposal of surface water from the site will not exacerbate existing flooding from all new development within Flood Zones 3 and 2 and from any development greater than 1Ha in Flood Zone 1 or within areas that are known to suffer from surface water drainage or sewer flooding.

A surface water drainage assessment should be undertaken to demonstrate that surface water runoff from the proposed development can be effectively managed without increasing flood risk elsewhere. A surface water drainage assessment should include the following:

- Assessment of whether the development will increase the overall discharge from the site by calculating the change in area covered by roofs and hard-standing.
- Details of how overland flow from the new development can be intercepted to prevent flooding of adjacent land.
- Details of how additional onsite surface water attenuation can be provided to mitigate against known flooding problems or as a result of incapacity on the drainage systems.
- Demonstration that overland flows will not increase flood risk to both existing development and receiving watercourses.
- Agreement that the rates of discharge from the development are acceptable to the Environment Agency and sewerage authorities.

**Selection of Appropriate Mitigation Measures**

The sequential approach should be applied within development sites to locate the most vulnerable elements of a development in the lowest risk areas. Where vulnerable development cannot be allocated within low risk areas then measures need to be put in place to mitigate against the flood risk.

There are several sources of information on potential mitigation measures, as follows:

- Flood Risk Assessment Guidance for New Development, Environment Agency R&D (FD2320)
- Development and Flood Risk – Guidance for the Construction Industry, CIRIA 624

The Environment Agency R&D Guidance on Flood Risk Assessments for new development suggests that mitigation measures can be split into three types:

- Measures that reduce the physical hazard, e.g. through raised defences or flood storage
- Measures that reduce the exposure to the hazard, e.g. raise properties above flood levels
- Measures that reduce the vulnerability to the hazard, e.g. flood warning or emergency planning.

The selection of appropriate mitigation measures depends on the requirements of the development and its sensitivity to flood risk. Any mitigation measure selected should be sustainable in the future by taking into consideration the impact of climate change on flood risk. The residual risk of developing an area vulnerable to flooding with mitigation measures in place should also be considered.

Flood defence walls or embankments

Flood defences, fully funded by the development can be constructed to protect a new development. However, the impact on the risk of flooding elsewhere with defences in place needs to be assessed and managed, for example, through the provision of compensatory storage. Residual risk of flooding with flood defences also needs to be assessed and managed.

Flood Storage

Flood storage either offline or online can be used to manage water levels at or downstream of a development site.

Building Design

Flood management measures only manage the risk of flooding rather than remove it completely. Therefore, buildings should be designed to be flood resistant and flood resilient where they are built behind flood defence systems. Flood resistance is the prevention of flood water entering a building through, for example, flood barriers or raising floor levels. Flood resilience is ensuring the finish (e.g. type of flooring) and services (e.g. electrics) are such that following a flood the building can be returned quickly to its normal operation. A basic level of flood resistance and resilience can be achieved through good building practice and complying with Building Regulations (ODPM, 2000).

Flood Warning

The Environment Agency provides flood warnings to a number of existing properties at risk of flooding to enable owners to protect life and manage the effect of flooding of their property. Flood warning should only be provided as a measure to manage residual risk and should not be used as the sole measure to offer protection to a development.

Access and Egress

PPS25 requires that safe access and escape is available to and from new developments in flood risk areas. Where possible, safe access routes should be located above design flood levels and an evacuation procedure should be in place for an extreme flood event. If safe access cannot be provided for all events then a safe haven of sufficient size to accommodate all occupiers of the development should be provided within the development.

For developments within Zone 3a High Probability and Zone 2 Medium Probability which are not offered protection from raised defences, the following is required:

- Dry escape, above the 100 year flood level taking into account climate change, should be provided for all 'more vulnerable' (including residential) and highly vulnerable' development.
- 'Safe' should be dry for all other uses such as educational establishments, hotels and 'less vulnerable' land use classifications.

For developments within Zone 3a High Probability and Zone 2 Medium Probability which are offered protection from raised defences, the following is required:

- 'Safe' access should preferably be dry for 'highly vulnerable' uses
- 'Safe' access should incorporate the ability to escape to levels above the breach water level.

For major 'highly vulnerable' development, safety will also need to be ensured through the development of a robust evacuation plan. This should clearly define routes to dry (i.e. 'un-flooded') land. This may include routes through flood waters, providing the depth and speed of flow across the evacuation route are below the risk defined by the "some" threshold in Flood Risk to People (Defra, FD2320)

For infrastructure development, safety will also need to be ensured through the development of a robust evacuation plan. This should clearly define dry escape routes (above the 100 year plus climate change flood level) to dry (i.e. 'un-flooded') land.

In exceptional circumstances, dry access (above the 100 year plus climate change flood level) for 'more vulnerable' and/or 'highly vulnerable' development may not be achievable. In these exceptional circumstances, liaison must be sought with the Environment Agency and the Council Emergency Planning Team to ensure that the safety of site tenants can be satisfactorily resolved.