Shropshire County Council

Shrewsbury

Strategic Flood Risk Assessment
Level 2

FINAL

August 2009

Halcrow Group Limited

Shropshire County Council

Shrewsbury

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Executive Summary

In March 2008 Shrewsbury and Atcham Borough Council (now Shropshire County Council) commissioned Halcrow to produce a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with Planning Policy Statement 25 (PPS25) and its Companion Guide, Making Space for Water (2003) and the new Severn Catchment Flood Management Plan (2008). The study comprises 1D-2D hydraulic modelling of the River Severn through Shrewsbury, to produce defended flood hazard maps for Flood Zones 2 (1 in 1000 year), 3a (1 in 100 year), 3a plus climate change (1 in 100 year +20%) and 3b (1 in 20 year). A series of breach hazard scenarios have been produced for the 1 in 100 year event: two at the Frankwell defences and one at the Coleham defences, both in Shrewsbury. The Coleham defences currently comprise works which provide a 1 in 50 year standard of protection. In addition to these defences, the modelling completed as part of this study includes the proposed defences at Coleham which will bring the scheme to a 1 in 100 year design standard.

The study refines and builds upon the work undertaken in the Level 1 SFRA, which included an assessment of flood risk from all sources. The need to undertake a Level 2 SFRA for Shrewsbury is driven by the need to redevelop brownfield sites in Shrewsbury in the future in order to maintain the long term prosperity of the town. Many potential development locations are otherwise in sustainable locations, but are often at risk of flooding posed by the River Severn (as well as Rea Brook in the Abbey Foregate area). This study therefore provides flood hazard information for a range of return periods and potential defence breach scenarios, in order to inform application of the Sequential and Exception Tests (by the Council), and the determination of the suitability of redevelopment of brownfield sites. Relevant policies for the management of flood risk and appropriate development of flood risk areas in Shrewsbury are then put forward. In addition, the study includes an assessment of some 73 potential development sites which may be taken forwards for development in the future. Their suitability for development has been assessed against flood risk information, to assist the Council with the Sequential Test process. The Environment Agency has been consulted throughout the study to ensure that the approach is robust and meets best practice.

The modelling results show that there are significant variations in flood hazard, both within the same return period and between different return periods, demonstrating that the hazard posed when an event occurs will not be uniform across the flooded area. The Frankwell and Coleham defences (which include proposed defences) have been shown to have a design standard of 1 in 100 years, but are both overtopped for the 100 year plus climate change event and the 1 in 1000 year event. Breach scenarios at Frankwell have also demonstrated that if a breach occurred during the 1 in 100 year event, inundation would be rapid, with fast, deep waters producing areas of extreme flood hazard. The area of inundation would be equal to if the defence wasn't there. At Coleham, a defence breach would cause slower inundation, with lower velocities and depths, but hazardous nonetheless. This demonstrates that development behind the defence would be very susceptible to flood risk as a result of climate change, indicating that new development should not be considered here. However, it is acknowledged that brownfield redevelopment may be required to ensure the long-term prosperity of the area and therefore sites may be considered should Sequential and Exception Tests be passed, provided the relevant policy recommendations are followed.

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1 Introduction

1.1 *Project Overview*

Halcrow Group Ltd has been requested by Shrewsbury and Atcham Borough Council (now Shropshire County Council) to undertake a Level 2 Strategic Flood Risk Assessment (SFRA). The aim of the study is to model the River Severn through Shrewsbury town centre (including a section of Rea Brook through Abbey Foregate) in order to consider the flood hazard posed to the area, the effect of the flood defences on flood risk and the potential effects of a series of breaches of the defences. The study refines and builds upon the work undertaken during the Level 1 SFRA which included a broad scale assessment of flood risk, using existing data, across the whole County and from all sources.

The River Severn flows from the north west across the area formerly known as Shrewsbury and Atcham Borough, meandering through the rural landscape before flowing through Shrewsbury town, where it is fed by both the Rad Brook and the Rea Brook. Shrewsbury town has a long history of flooding problems, with notable events occurring in 1795, 1941, 1946, 1947, 1960, 1964, 1965, 1968 and more recently in 1998, 2000 and 2002. In the autumn of 2000, the worst flooding for over 50 years caused widespread damage along the length of the River Severn. Shrewsbury was badly affected and the town was extensively flooded three times in the space of six weeks. As a result, the Environment Agency accelerated a feasibility study to investigate the provision of flood defences for the town. Defences now exist in Frankwell and Coleham (with further flood defence works planned for Coleham in the near future).

Despite the flood risk posed to areas of the town, Shrewsbury requires the continued re-development brownfield sites in order for the area to remain prosperous and to ensure its longevity. Potential sites along the River Severn corridor, including the Frankwell and Abbey Foregate areas, are otherwise in sustainable locations but due to the flood risk posed, it is necessary to carry out a Level 2 SFRA to allow informed decisions to be made to satisfy the Sequential Test and Exception Test, where required. New sites which come forward in the future as part of the Unitary Development Framework may also require a Level 2 SFRA at a later date.

As part of the Level 2 assessment, the existing River Severn and Rea Brook one dimensional (1D) models have been linked in order for the important confluence area around Rea Bridge to be modelled. The models have been trimmed to cover the Shrewsbury town area. The combined 1D model has then been linked to LiDAR ground elevation data in order to model the floodplain area in 2D. The use of a 1D-2D linked model allows the creation of depth, velocity and hazard maps.

It has been necessary to include defences in the model in order to assess the impact these have on both flood risk and flood hazard. The Frankwell scheme (including the demountable sections) was included in the model, as well as the existing and proposed defences at Coleham (again including the demountable sections). Further details on the defences can be found in Sections 4.4 and 4.5.

The defended model was run for the following return key periods: 1 in 20, 100, 100 plus climate change and 1000 year events to represent Flood Zone 3b, Flood Zone 3a, Flood Zone 3a plus climate change and Flood Zone 2 respectively. The 2D software TUFLOW has been used to produce peak flood extents, depths and flow velocities within the floodplain, allowing the production of hazard maps for each return period. The modelling outputs have then been used to inform appropriate flood risk management policies for the areas affected.

Defence breaches were also modelled at three locations: two at Frankwell (upstream of Welsh Bridge (SJ 49052 12866) and downstream of Welsh Bridge (SJ 48805 12784)) and one at Coleham (SJ 49702 12272). Inundation maps have been produced using the 2D software TUFLOW.

The Level 2 SFRA has been prepared in accordance with best practice, Planning Policy Statement 25: Development and Flood Risk (PPS25). The Environment Agency's Development Control and Flood Risk Mapping teams have also been consulted through all stages of the assessment, and both modelling and mapping methodologies have been discussed with the Environment Agency to ensure acceptance of the Level 2 SFRA approach.

The SFRA is a living document. As new flood risk information becomes available (such as updated Flood Zone information and more extensive information on flooding from other sources) it should be incorporated into the SFRA. The modelled outputs produced as part of this Level 2 SFRA form a complimentary data set to the existing Environment Agency Flood Zone maps. It should also be ensured that the latest Environment Agency Flood Map is used as part of the planning process unless further more detailed work has been undertaken which has been accepted by the Environment Agency.

1.2 *Aims & Objectives*

In September 2007 a Level 1 SFRA was produced by Halcrow for Shropshire County Council and the Unitary Authority, Telford and Wrekin, in accordance with PPS25. Following this study Shrewsbury and Atcham Borough Council identified the need for a Level 2 SFRA in order to facilitate application of the Sequential and Exception Tests (as possible future site allocations and regeneration sites are identified in zones of higher flood risk). This study focuses on proposed development in Shrewsbury itself. In addition, all potential site allocations have been assessed against flood risk data, the findings and recommendations of which can be found in Appendix A. Where potential site allocations have fallen within the area of hazard mapping on the River Severn and Rea Brook undertaken as part of this project, these have also been assessed, as detailed in Appendix B.

1.2.1 *Aim*

The main aim of the Level 2 SFRA has been to develop a 1D-2D linked hydraulic model of the River Severn through Shrewsbury to assess the flood hazard posed for a range of return periods. A series of breach scenarios were also required. A location map can be viewed in Figure 1. Note that prior to the finalisation of this study, Shrewsbury and Atcham Borough Council ceased to exist, becoming part of the Shropshire County Council Unitary Authority.

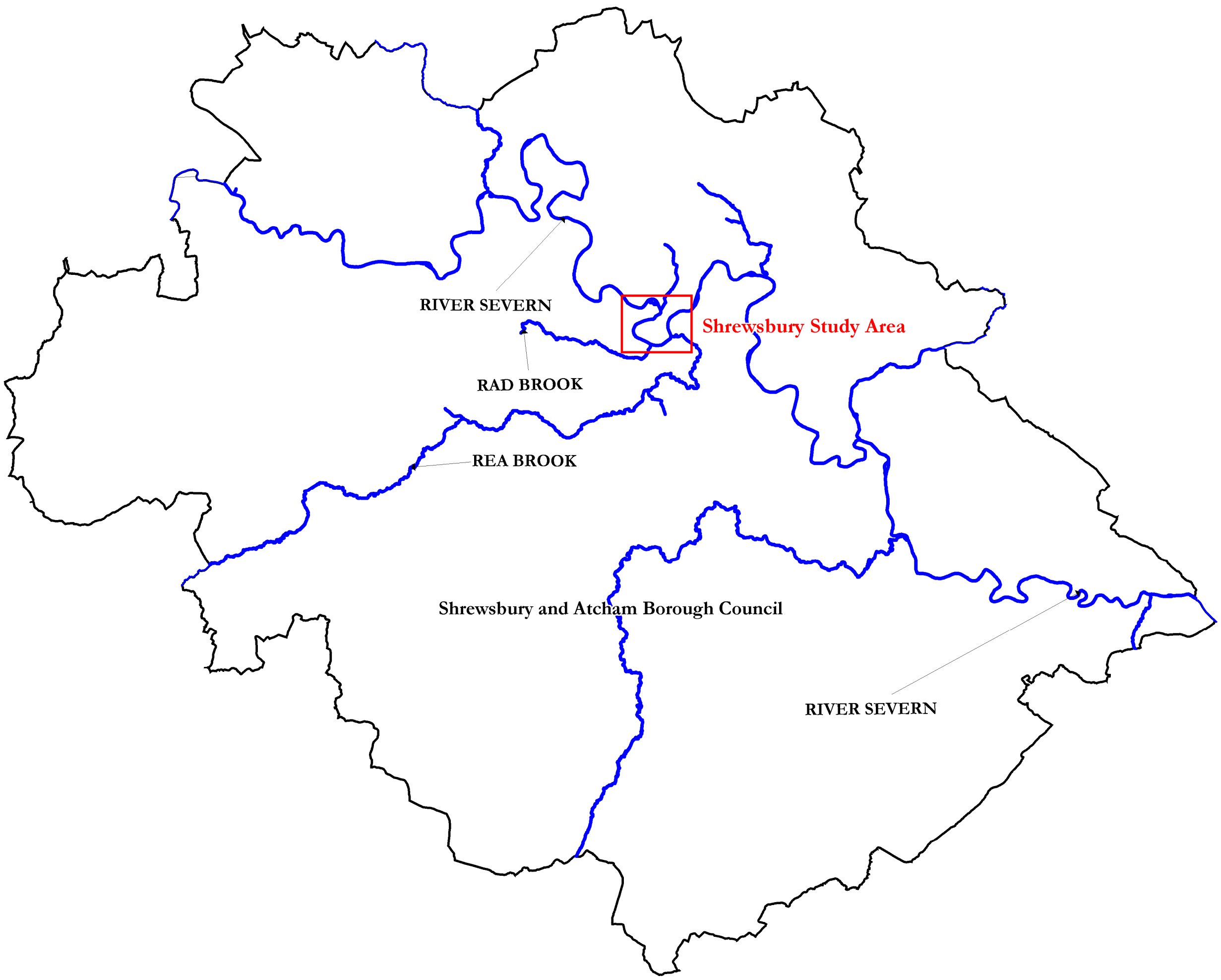

Figure 1: Study Area

1.2.2 *Main Tasks*

The main tasks of this study are to:

- Develop a linked 1D-2D hydraulic model for the River Severn and Rea Brook through Shrewsbury using existing 1D models and Digital Terrain Models (DTM) derived from LiDAR survey data – the 2D aspect of the model allows modelling not only of the flood extent, but also the depth and velocity of out-of-channel flows.
- Include the Frankwell and Coleham defences (both existing and proposed) in the model

- Carry out a series of breaches of the Frankwell and Coleham defences and produce inundation maps
- Produce Flood Zones 2, 3a, 3a plus climate change and 3b (defended scenarios)
- Produce flood maps showing:
  - (i) Flood Extent
  - (ii) Flood Depth
  - (iii) Flood Velocity
  - (iv) UK Flood Hazard – derived from flood depth, velocity and UK hazard debris factor.
- Assess potential site allocations against Level 1 SFRA data and where applicable, against new modelling outputs produces as part of this study
- Develop appropriate policies for flood affected areas through Shrewsbury
- Provide appropriate Development Control policies and FRA guidance for developers

1.3 Background to the study area

Shrewsbury is a medieval market town, with a rich history and a wealth of fine historic buildings. There is a radial network of roads emanating from the Shrewsbury urban area into the rural surroundings. Most of the larger rural settlements lie on these radial highways. Some spectacular countryside surrounds Shrewsbury, including the northern extremities of the Shropshire Hills Area of Outstanding Natural Beauty on the southern fringes. In the extensive rural areas agriculture is the principal land use.

There are a number of designated main rivers in the area formerly known as Shrewsbury and Atcham Borough, all of which are tributaries of the River Severn:

- River Severn, flowing directly through the centre of the Borough in a north-west to south-east orientation

- River Perry, flowing into the north-western side of the Borough in a north to south orientation, joining the River Severn to the north-west of Shrewsbury

- Rad Brook, flowing in a west to east orientation along the western fringes of Shrewsbury and entering the River Severn at the southern tip of the Severn meander in the centre of the town

- Rea Brook, entering the Borough from the south-west and flowing in a south-west to north-east orientation to meet the River Severn just downstream of the Rad/Severn confluence in central Shrewsbury

- River Roden, entering the north-western edge of the Borough and flowing in a north-east to south-west orientation to meet the River Severn just outside of Shrewsbury

The source of the River Severn can be found at Plynlimon in the Welsh Mountains. The Upper Severn area is undulating as would be expected from an upper catchment, dominated on the western edge by the Cambrian Mountains and characterised by steep-sided, incised river valleys. The River Severn drops quickly from 741m AOD (Above Ordnance Datum) at Plynlimon to 198m AOD at Llanidloes, just 19km downstream.

1.4 Strategic Flood Risk Assessment

1.4.1 *SFRA Aims*

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

The aim of a SFRA therefore is to map all forms of flood risk and use this as an evidence base to locate new development primarily in low flood risk areas (Zone 1). Much of this work has been completed as part of the Level 1 assessment, with subsequent Level 2 work required to fully guide the planning and development control processes.

Flood Zones are referred to as follows:

- Flood Zone 1 (Low Probability): This zone comprises land assessed as having less than a 1 in 1000 year annual probability of river or sea flooding in any year (>0.1%)

- Flood Zone 2 (Medium Probability): This zone comprises land assessed as having between a 1 in 100 (1%) and 1 in 1000 (0.1%) annual probability of river flooding in any one year.

- Flood Zone 3a (High Probability): This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding in any one year.

- Flood Zone 3b (Functional Floodplain): This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

It should be noted, however, that flooding from sources including sewers, surface water, groundwater and impounded water bodies (such as reservoirs and canals) can occur in any zone.

Where development cannot be located in Flood Zone 1 the planning authority will need to apply the Sequential Test to land use allocations and, where necessary, the Exception Test. In addition, the SFRA allows the planning authority to:

- Prepare appropriate policies for the management of flood risk;
- Inform the sustainability appraisal so that flood risk is taken account of when considering options and in the preparation of strategic land use policies;
- Identify the level of detail required for site-specific Flood Risk Assessments, and
- Determine the acceptability of flood risk in relation to emergency planning capability.

The findings of a SFRA will feed directly into the preparation of Local Development Documents (LDDs).

1.4.2 *Level 2 Strategic Flood Risk Assessment*

According to the PPS25 Practice Guide (2008), the principal purpose of a Level 2 SFRA is to facilitate the application of the Sequential and Exception Tests. The Exception Test is applied when there are an insufficient number of suitably available sites for development within zones of lower flood risk or due to possible increases in flood risk arising from climate change.

For the Exception Test to be passed:

a) It must be demonstrated that the development provides wider sustainability benefits to the community which outweigh flood risk, informed by a SFRA where one has been prepared. If the Development Plan Document has reached the 'submission' stage (see Figure 4 of PPS12: Local Development Frameworks) the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal;

b) 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,

c) A flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

It is possible that Council will need to apply the Exception Test to future land allocations or brownfield re-developments, due to Shrewsbury town centre's proximity to the River Severn. The purpose of this study is to provide the necessary information for this to be carried out as the need arises.

The increased scope of the Level 2 assessment involves a more detailed review of flood hazard within a Flood Zone (including flood probability, flood depth, flood velocity and the rate of onset of flooding) taking into account the presence of flood risk management measures such as flood defences. This also includes 2D modelling and breach/overtopping analysis for certain locations where the residual risk of failure of existing water retaining structures may impact on future development.

The Level 2 SFRA, in conjunction with the Level 1 SFRA, will enable the Council to fully apply a Sequential Test approach at the site allocation level (vulnerable uses within the site to be directed to areas at the lowest probability of flooding in the first instance) and will inform policies and practices to ensure that where necessary any development in such areas satisfies the requirements of the Exception Test.

1.5 UK Flood Hazard

In addition to the TUFLOW outputs of depth and velocity, the UK Flood Hazard is also calculated by the model. The output includes a grid of Flood Hazard derived from the flood depth and velocity outputs and a debris factor. The Hazard and its associated classification are calculated within TUFLOW. The UK Flood

Hazard is calculated by using the following equation from Defra's Flood Risks to People – Phase Two Document (FD2321/ TR2) (2006). Hazard is calculated as follows:

Hazard = d x (v + 0.5) + DF

Where **d = depth (m)**

V = velocity (m/s)

DF = debris factor

Based on the value of the hazard for a given area, a Hazard Classification is then assigned. The Flood Hazard classifications are divided into four classes of risk:

Table 1: Flood Hazard Rating and Associated Category

Flood Hazard Rating	Category
0.0 – 0.75	Low
0.75 – 1.25	Moderate
1.25 – 2.5	Significant
2.5 +	Extreme

These classes of risk then translate into the following Flood Hazard classification (Figure 2):

- Class 1: Danger for some – Flood zone with deep or fast flowing water that presents a hazard for some people (i.e. children)

- Class 2: Danger for most – Flood zone with deep or fast flowing water that presents a hazard for most people

- Class 3: Danger for all – Flood zone with deep or fast flowing water that presents a hazard for all people

For example, if peak water depths are 1.0 m, for velocities less than 1.0 m/s, the flooding is considered to present 'Danger for some'. For velocities between 1.0 m/s and 2.0 m/s the flooding is considered to present 'Danger for most'. For velocities greater than 2.0 m/s the flooding is considered to present 'Danger for all'.

Figure 2: Flood Hazard Classification

1.6 *Flood Risk Management Strategies - Environment Agency*

The work undertaken and recommendations provided in Level 2 SFRAs should be in accordance with the relevant Catchment Flood Management Plan (CFMP) covering the study area, in this case, the River Severn CFMP. At the time of production of the Level 2 SFRA, the original Severn CFMP had been updated and the new, finalised report became available.

Shrewsbury town falls in the Policy Unit 'Middle Severn Corridor'. Here, the CFMP identifies the following opportunities and constraints:

- There are opportunities to implement SUDS within urban areas as well as the promotion of PPS25 which will help to reduce risk to new developments.

- Attenuation in the upland areas of the catchment, particularly within the Severn and Vyrnwy Uplands Policy Unit, has the ability to reduce peak discharge across much of the Severn Catchment which would be beneficial for this Policy Unit.

- Increased uptake of the Environmental Stewardship Scheme will help farming practices reduce run-off from agricultural land.

- The extension of Flood Warning areas within the catchment has potential for allowing many more people at risk of flooding to receive the service.

- The promotion of flood proofing schemes will help to mitigate the affects of flooding where building defence structures is not an option.

- Many of the urban areas in the Policy Unit, such as Shrewsbury and Worcester have been identified for urban development in the future.

- Need to protect sensitive environmental areas.

- Many urban areas in the catchment experience problems in surface water flooding which occurs in addition to fluvial flooding.

The selected Policy Option for the area is to 'take further actions to sustain the current level of risk into the future (responding to the potential increase in risk from urban development, land-use change and climate change). Identified actions are as follows:

- Close communication between Environment Agency Development Control and Local Planning Authority to ensure the implementation of PPS25.

- Determine the role of the agricultural defences in flood risk management within the catchment using Asset Management Plans and Strategic Asset Management Plans.

- Review of annual maintenance expenditure.

- Maintain Flood Warning and Flood Watch areas.

- Conservation and land management advisers working with other land managers to promote Environmental Stewardship Schemes

- Assess the impact of future flood risk management activities on SSSIs using Habitat Management Plans.

The suggested policies contained in this document therefore take strong direction from the recommended actions for Shrewsbury identified in the CFMP, as well as the recommendations of PPS25, Making Space for Water and the Water Framework Directive.

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2 Planning Context

2.1 *Regional Context*

The West Midlands Regional Spatial Strategy (RSS) 11 Phase Two Review sets out housing allocations for each district within the West Midlands between 2006 and 2026. The proposed net total of housing growth for 2006-2026 is currently 365,600 and the indicative annual average growth for the same period is currently 18,280. The following growth figures exist for Shrewsbury and the Borough:

Table 2: Proposed growth in Shrewsbury and the Borough as set out in the West Midlands Regional Spatial Strategy

Planning Area	Proposal Total (Net) 2006-2026	Indicative Annual Average 2006-2026
Shrewsbury and Atcham	8,200	410
of which Shrewsbury	6,200	310

The current WMRSS has adopted a fundamental change in strategic policy direction to achieve urban and rural renaissance, where the central aim is for the Major Urban Areas (MUAs), wherever possible, to meet their own economic and social needs within their own boundaries and to limit migration. In other parts of the Region, new development will be focused in and adjacent to towns which are most capable of balanced and sustainable growth to complement the role of MUAs. The RSS Phase Two Revision maintains the existing RSS strategy, but responds to higher growth. Beyond the MUAs, therefore, growth is now intended to be focussed in WMRSS Settlements of Significant Development (SSDs), representing towns that are capable of balanced and sustainable growth, forming sustainable communities, with development primarily aimed at meeting the economic and social needs of the area rather than attracting out-migration from the MUAs. Ten areas have been designated as SSDs in the West Midlands, of which Shrewsbury is one. Provision for housing and other new development will generally be concentrated in these SSDs. Here, the aim is to provide for the economic and social needs of the area and to limit migration from the MUAs.

In addition, the Government's New Growth Points initiative is designed to provide support to local authorities who want to pursue large scale and sustainable growth. There are nine Growth Points in the West Midlands, of which Shrewsbury and Atcham Borough is one.

2.2 *Local Planning Policy*

In July 2007 the Government announced that Shropshire would be one of a handful of areas where its local government structure would be changed, replacing the current two tier system with a Unitary Council. This will mean that as of April 2009 the six existing authorities of Shropshire County Council, Bridgnorth District Council, North Shropshire District Council, Oswestry Borough Council, Shrewsbury and Atcham Borough Council and South Shropshire District Council will be merged to form a single Shropshire wide Unitary Council. All the services currently provided by these authorities, including the planning service, will be transferred to the new authority. The new Council started work on 1st April 2009. Consequently work on Shrewsbury and Atcham Borough's Local Development Framework (LDF) has ceased. However, the evidence base collected for the Borough's LDF will be rolled forward to input into the Unitary Council's LDF. The SFRA (Level 1 and Level 2) will form part of this evidence base.

As part of the move to the new Unitary Council for Shropshire, the County's existing local authorities have started working together on a new Shropshire wide LDF. The first document to be prepared for the new LDF will be the Core Strategy, which will set the strategic policy framework for new development in the county over the next 15 to 20 years. On adoption, the LDF will replace the current Local Plans for all the Districts in Shropshire and the County Council's Waste Local Plan. The LDF portfolio will contain:

- Development Plan Documents (DPDs) that are subject to community involvement as well as independent testing (by the Planning Inspectorate) and have 'Development Plan' status

- Supplementary Planning Documents (SPDs) that are subject to rigorous community involvement, but are not tested by the Planning Inspectorate and do not have 'Development Plan' status.

As part of the early development of the Core Strategy a series of Topic Papers have been prepared on a range of important planning issues. The timetable for preparation of the Unitary Council's LDF can be found in the draft joint Local

Development Scheme (LDS), as approved by the Implementation Executive on 9th April 2008 (Table 3). The Local Development Scheme sets out:

- The present Development Plan(s) for Shropshire and the existing policies that will be saved, the LDDs that are to be prepared over the forthcoming 3-year period to replace existing policies, and whether they are to be DPDs or SPDs

- The subject matter and the geographical area to which each LDD relates

- Which organisation is to lead the process of each LDD preparation and, if any, are to be prepared jointly with other local planning authorities

- The arrangements for future monitoring of the LDF, including the timetable for the preparation and review of the LDDs.

Table 3: Indicative dates for production and adoption of LDDs

Document Title	Brief Description	Date of Issues & Options Consultation (DPDs only)	Date for Submission to Secretary of State	Proposed Date for Adoption
Local Development Scheme	Document setting out programme for preparation of LDDs	N/A	April 2008	N/A
Statement of Community Involvement	Document setting out how the Council intends to engage the community and other organisations on DPDs and SPDs and the development control process.	N/A	March 2009	June 2009
Core Strategy	The Core Strategy will set out the Council's vision, objectives and spatial strategy to guide future development of the Borough together with core strategic policies	December 2008	March 2010	February 2011
Site Allocations	Document identifying sites proposed for development to meet the housing, employment land, retail and services requirements and other objectives of the Core Strategy	November 2009	June 2011	May 2012
Minerals DPD	Specific minerals policies and site allocations	November 2009	June 2011	May 2012
Waste DPD	Specific waste policies and site allocations	December 2010	March 2012	Decembe r 2012

The Planning and Compulsory Purchase Act (2004) contains transitional arrangements to enable the move between the old and new development plan system. The transitional arrangements enable policies and proposals in existing Structure and Local Plans to be 'saved' for a period of three years from commencement of the Act (September 2004) or, for a Local Plan still progressing to adoption under the old style system, from the date of its adoption.

In Shropshire's case this meant that the following plans were 'saved' in full until September 27th 2007:

- Shropshire and Telford & Wrekin Joint Structure Plan 1996-2011;
- Shropshire and Telford & Wrekin Minerals Local Plan 1996-2006;
- Shropshire Waste Local Plan 2002-2014
- Oswestry Borough Local Plan
- Shrewsbury and Atcham Borough Local Plan
- South Shropshire District (adopted April 2005)

In applying to extend the 'saved' period of policies in these plans, each policy had to be assessed against a strict criteria set by the Department for Communities & Local Government and a reasoned argument prepared for each. In general, where it was considered that a policy continued to be necessary for development control decision making in Shropshire, and where these policies had not been superseded by higher level regional and national policy, the relevant local authority applied to extend the 'saved' period for these policies beyond September 2007. Further detail on saved policies from each of the above Plans can be obtained from the relevant authority's website. All such 'saved' policies will continue to form part of the 'Development Plan' for Shropshire until appropriate replacement policies in LDFs and Regional Spatial Strategies (RSSs) are prepared and adopted, or until they are superseded by national policy changes.

It should also be noted that Shrewsbury urban area has been identified by the government as a New Growth Point (NGP) in recognition of its status as a sub regional centre that will be required to provide significant housing growth over the next 20 years.

In line with PPS25 and the living draft practice guide companion, this SFRA will enable the preparation of appropriate policies for the management of flood risk within the LDF DPDs and inform the Sustainability Appraisal process in order that flood risk is taken into account when considering development options and the preparation of strategic land use policies.

3 Site Assessment

3.1 *Overview*

At the time of commissioning this study, Shrewsbury and Atcham Borough Council was aware of developer interest in some 73 potential development sites, which will need to be considered through the Local Development Framework process. To assist the Council with the site assessment process, this study has included an assessment of the flood risk posed to each of these sites, with associated recommendations. The results of the assessment are tabulated in Appendices A and B.

Two sets of site assessment have been undertaken. Appendix A assesses sites which do not fall in the modelled area of study undertaken as part of this Level 2 study. This assessment has used the Flood Zone data collected in the Level 1 SFRA (though a check has been made with the latest Environment Agency Flood Map to ascertain if any changes have been made to the Flood Zones; where they have, the latest Flood Zone data has been used), which included mapping the flood risk posed from sources other than fluvial. Appendix B assesses sites which do fall in the modelled area of study undertaken as part of this Level 2 SFRA, i.e. along the River Severn and Rea Brook through Shrewsbury. An assessment of the flood hazard posed to each site has therefore been undertaken in Appendix B. Recommendations are in accordance with the Level 1 SFRA and relevant guidance including PPS25.

It should be noted that the Flood Zone maps through Shrewsbury produced as part of the Level 2 SFRA include defences. The Level 2 SFRA Flood Zones have been reviewed against the Environment Agency's undefended Flood Zone information (Flood Zone 3b was provided as part of the Level 1 SFRA). This indicates that Flood Zones 3a and 3b match very well with the undefended flood zones, except in areas behind the Coleham and Frankwell defences, as would be expected. The Environment Agency's Flood Zone 2 is produced from JFLOW, therefore the Level 2 SFRA Flood Zone 2 has provided a more detailed assessment, which does vary in places. Otherwise there is only one area where the Level 2 SFRA Flood Zones vary from the Environment Agency's Flood Zone information, details of which are included in Appendix B. Where sites have been found to be located in an area benefitting from a defence, recommendations are provided firstly on the basis of the undefended flood map. Should the site pass the Sequential Test, information is given on the residual risk posed to the site using the defence breach information, to determine if the site is suitable for development (thereby assisting the Exception Test, where required).

The aim of the site assessment is to assist the Council in gaining a detailed overview of each site, to assist the Sequential Test process. Specific recommendations are given for each site in Appendices A and B. For sites which are affected by flood risk, the primary recommendation is for the Council to consider sites in Flood Zone 1 in preference. The assessment assumes that the Council will then undertake the Sequential Test, and guidance for development of the site is then given, should the Sequential Test be passed. Section 6.5 gives guidance of the requirements for development in each Flood Zone, and it is imperative this guidance is followed. For sites which would need to pass the Exception Test, Appendices A and B firstly recommend that appropriate alternative in lower risk Flood Zones are developed in preference. In Appendix B, it has been possible to assess the flood hazard posed to sites and therefore determine if the level of risk can be sufficiently mitigated, therefore going some way to assist with the Exception Test, should it need to be applied.

Chapter 5 assesses the flood hazard posed through Shrewsbury and Chapter 6 puts forward suggested policies for future development in Shrewsbury. The council should assess the feasibility of future redevelopment proposals and windfall sites in Shrewsbury against the modelling and policy outputs of this study.

3.2 General Points to Note

The DG5 data received from Severn Trent Water coarsely illustrates the number of properties within a four-digit postcode polygon (e.g. SY1 6) which have been flooded by either foul, combined or surface water sewers. Figure 3 shows that historically, sewer flood incidents have occurred in the north and west of the Borough and around the Shrewsbury area the number of sewer flooding incidents is fairly high. Table 4 outlines the number of years for which incidents have been reported within each polygon area. However, it should be noted that the resolution of data available for this assessment is very course and therefore limits its use for spatial planning. It is also likely that improvements to the drainage system have mitigated these problems. The Frankwell flood defence scheme included major improvements to the drainage system, including the construction of two new large pumping stations by Severn Trent Water Ltd. These reduce the risk of flooding due to backing up of the drains. Under normal circumstances, the pumping stations operate automatically. However, they are monitored remotely from the Severn Trent Water control room and can be operated manually if required, thereby reducing residual risk of pump failure. Severn Trent Water acts upon flood warnings issued by the Environment Agency by sealing off parts of the sewerage system from the river and operating pumping equipment in order to prevent flooding from the public sewers. However, this does not remove the risk of sewer and surface water flooding, which should be assessed at the site-specific level through a Flood Risk Assessment (FRA).

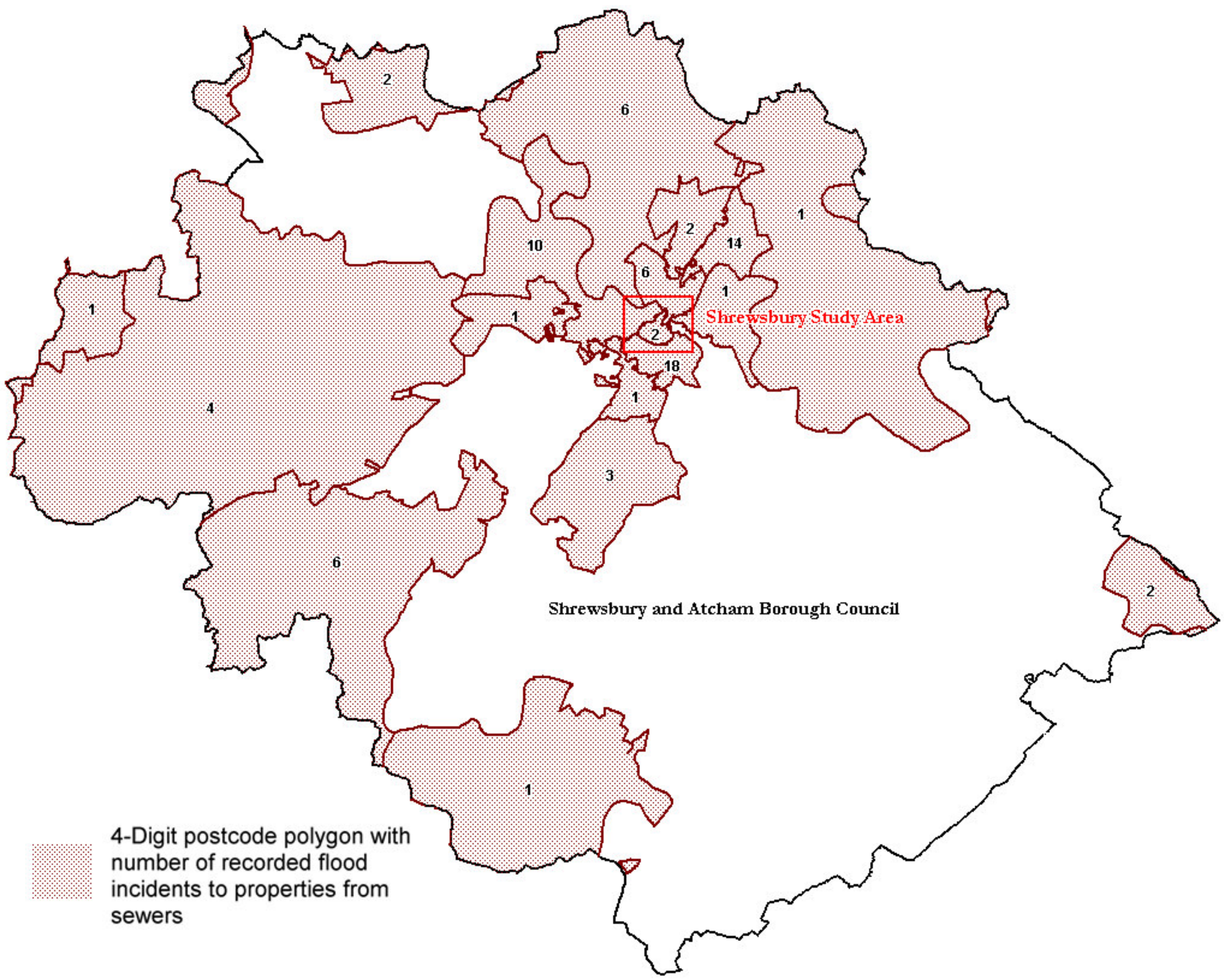


Figure 3: Sewer Flood Risk Data for Shrewsbury & Atcham

Table 4: Number of reported incidents within each postcode area and the number of years over which incidents have been reported

Postcode Area	Number of Reported Incidents	Number of Years over which incidents reported
SY1 2	6	8
SY1 3	2	1
SY1 4	14	6
SY2 5	1	1
SY3 0	3	5
SY3 5	1	1
SY3 7	18	11
SY3 8	10	8
SY3 9	1	1
SY4 2	2	1
SY4 3	6	5
SY4 4	1	3
SY5 0	6	3
SY5 9	4	6
SY6 6	1	1
TF8 7	2	2
SY21 8*	1	1

3.3 Site Selection Process

The Sequential Test Process as advocated by PPS25 (Appendix C) should be carried out for all potential development sites.

Potential sites identified in Flood Zone 1 are generally suitable for development, as long as the recommendations for development in Flood Zone 1 are followed (Section 6.5).

Sites which mainly lie in Flood Zone 1, but are affected in some way by Flood Zones 2, 3a and 3b, should only be developed if there are no other suitable sites lying fully in Flood Zone 1. If this can be demonstrated, such sites are generally suitable for development provided that the Council/developer adopts the principle of **avoidance**, ensuring that the area of Flood Zone 2, 3a and 3b remains as undeveloped open space. This is especially important where Flood Zone 3a is shown to affect the site, which has been assumed to equal Flood Zone 3b where no 3b exists to differentiate. The avoidance of flood risk is important in the development of sustainable communities and will deliver a positive reduction in flood risk by reducing the impact that flooding may have on the community (by reducing the number of people within the site that would otherwise be at risk). It can also help the Council to achieve green space targets. This approach is generally appropriate when an area of 10% or less of the site is affected by Flood Zones 2, 3a and 3b. Appendix A identifies a number of sites of this nature, and in instances where the Flood Zones have been derived from JFLOW, an FRA will be required to confirm the level of flood risk posed to the site, and ensure these risk areas remain as open space.

Provided that the Sequential Test process has been carried out and passed, sites falling in whole or in part in Flood Zones 2, 3a and 3b can be developed **but only in accordance with Table D3 of PPS25** (Table 5), **carrying out the Exception Test where indicated.** It is important to ensure that sites fully in Flood Zone 1 are considered in preference to the development of sites in higher risk areas, and sites in higher risk areas should only be developed if it can be demonstrated that no alternative site in Flood Zone 1 are suitable. Appendix A strongly recommends that when sites are affected by Flood Zones 2, 3a and 3b, these areas remain as open space.

Where sites within (or affected by) Flood Zones 2, 3a and 3b will be developed after passing the Sequential Test (and where relevant, the Exception Test), the Council/developer should **substitute** less vulnerable development types for those incompatible with the degree of flood risk. The land should be developed sequentially; i.e. the layout of the development should be planned so that the development types within each Flood Zone are in accordance with the requirements of Table D3 of PPS25 (Table 5). An example is given in Figure 4. Further, the guidelines for development in Flood Zones 2, 3a and 3b must be followed (as outlined in Section 6.5).

Table 5: Flood Risk Vulnerability & Flood Zone 'Compatibility' (D3 PPS25)

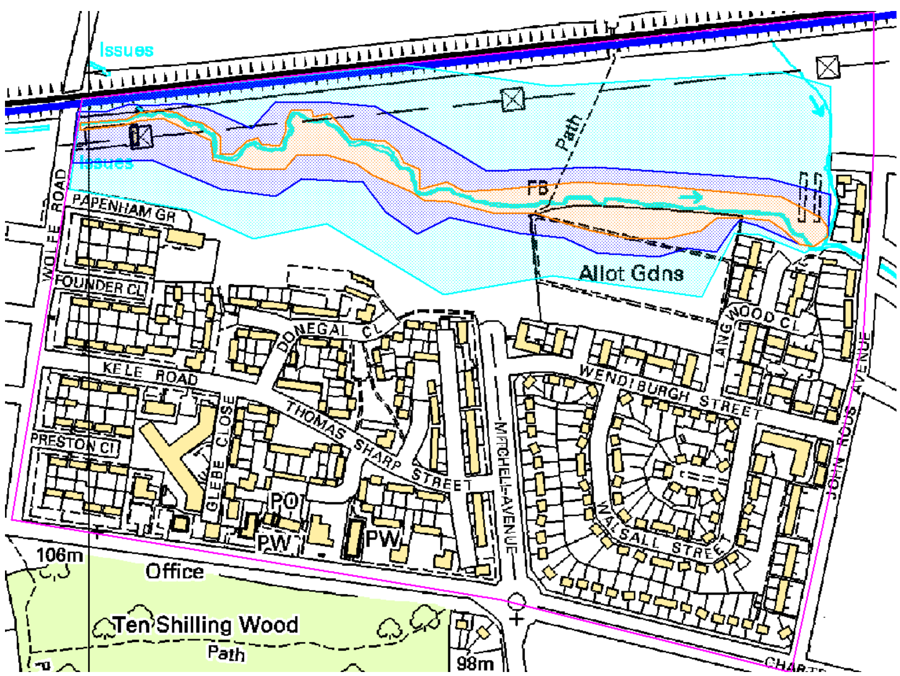
Flood Risk Vulnerability classification (see Table D2)		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (see Table D.1)	Zone 1	✔	✔	✔	✔	✔
	Zone 2	✔	✔	Exception Test required	✔	✔
	Zone 3a	Exception Test required	✔	✗	Exception Test required	✔
	Zone 3b 'Functional Floodplain'	Exception Test required	✔	✗	✗	✗

Key:

✔ Development is appropriate

✗ Development should not be permitted

Figure 4: Example of correct master planning of a site affected by flood risk



Appendix A illustrates that in some cases, potential development sites fall in areas which will be wholly inappropriate for the type of land use proposed. In such instances it has been recommended that alternative sites in lower risk areas are considered in preference.

Section 6.5 includes key requirements for development in Flood Zones 1, 2, 3a and 3b, which should inform developers' FRA requirements and be used to deal with non-allocated 'windfall' sites.

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4 Hydraulic and Hydrological Approach

4.1 *Hydraulic Approach*

A 1D iSIS model of the River Severn has been produced by the Environment Agency, which has been utilised for this study. A 1D model of the Rea Brook has also been produced by the Environment Agency and this was linked to the River Severn model (it was originally supplied in Hec-Ras format and was converted to iSIS).

1D hydraulic modelling of open channels is a principal method of hydraulic modelling used for the assessment and management of flood flows and consist of linked cross-sections derived from channel survey data. Originally, the River Severn model included extended cross-sections of the floodplain to enable the mapping of the flood extent, but this did not enable the production of maps depicting flood depth or velocity.

As part of the Level 2 SFRA, there is requirement to understand the flood hazard posed by out of bank flows, therefore requiring an assessment of flood depth and velocity. An advantage of iSIS is that it can be linked to 2D models such as TUFLOW, which describe the spatial distribution of the flow. The linked 1D-2D model allows the channel to be well defined in 1D, while the extended floodplain areas can be described using a 2D representation, therefore giving flood depth and velocity information. Topographic data for the model floodplain (2D extents) was provided by the Environment Agency in the form of LiDAR data.

It was not necessary to use the entire extent of the River Severn or Rea Brook models, therefore the models were trimmed. The modelled extents are as follows:

- River Severn upstream extent: SJ 47560 13740
- River Severn downstream extent: SJ 50620 14100
- Rea Brook upstream extent: SJ 50480 11800
- Rea Brook downstream extent (confluence with River Severn):SJ 49650 12270

The modelled extents cover a larger area than the River Severn river loop through Shrewsbury town for modelling purposes, but for the purposes of the study the main analysis has focused on the section of the River Severn from Mountfields to Cherry Orchard and from the River Severn/Rea Brook confluence to Haycock Way. The results produced for the whole modelled section are provided and could be utilised by the Council if required.

The main structures on the River Severn and Rea Brook were already represented in the original models and have remained in the Level 2 SFRA model. Section 4.3 discusses the defences that were included in the model.

4.2 Hydrological Approach

The existing River Severn hydrology, undertaken as part of the original River Severn modelling project, has been utilised for this study. Runs had previously been carried out by the Environment Agency for the 1 in 25 year, 1 in 100 year and 1 in 150 year events. For the purpose of the SFRA, some adjustments to the flow boundaries were necessary to derive flood hydrographs for alternative return periods required for this study. The following was adopted:

- For the 1 in 20 year run, the existing 1 in 25 model was taken and the flood return period was changed in each flow boundary to 20 years and the rainfall return period to 33 years

- The existing 1 in 100 year model and hydrology was used (for hydrological consistency, it was ensured that the flows at the upstream and downstream extents of the trimmed Level 2 SFRA River Severn model were equal to those in the original River Severn model)

- For the 1 in 100 plus climate change run, the existing 1 in 100 year model was taken and all inflows were increased by +20%

- For the 1 in 1000 year runs the highest return period previously modelled possible (1 in 150 year) was taken and the flood return period and the rainfall return period changed to 1000 years

4.3 Model Calibration

The original River Severn and Rea Brook models have been calibrated by the Environment Agency, therefore further calibration was not required for the Level 2 assessment.

4.4 Defences

Two flood defence schemes exist in Shrewsbury which were not included in the original River Severn or Rea Brook models. In order to produce 'defended' flood scenarios for Shrewsbury, the defences have been included in the Level 2 SFRA model.

The Frankwell flood defence scheme combines traditional stone clad floodwalls and embankments with new demountable defences. These are only erected in the event of a flood. For the majority of the year, when the river is not a threat, they are not there. The Environment Agency is responsible for the storage and erection of the demountable defences and when not in use, the barriers are stored locally. The nature of the process of erection of the demountable section of the defences means it is highly unlikely that the demountables would not be erected in time for a flood event, hence the Environment Agency has advised that they are included in the study.

The flood defences principally consist of steel sheet pile underground walls up to 16 metres deep, which limit the flow of groundwater under the defences. They also act as a foundation for reinforced concrete walls up to 3 metres high and demountable aluminium barriers. The longest single section of demountable defences is along the 'promenade' at Frankwell Quay, an area that has been significantly enhanced as a result of the scheme. The demountable elements have been standardised as far as possible. This means that most of the elements are fully interchangeable. The post spacing is at 3 metre intervals and the heights of the posts are either 1.5 metres (e.g. along the promenade) or 3 metres (e.g. across the car park entrance). There is also an exit from the Frankwell car park that allows vehicles to leave the car park even when all the demountable defences are in place. As discussed in Section 3.2, the works have also included major improvements to the drainage system, including the construction of two new large pumping stations by Severn Trent Water Ltd. These reduce the risk of flooding due to backing up of the drains.

The Coleham flood defence scheme currently combines raised walls and demountable defences upstream of English Bridge. Work to prepare the site began in October 2007. Developers contributed £786,600 from the Gay Meadow redevelopment with an additional £1.4m coming from Environment Agency capita funding, namely the Flood Defence Grant in Aid. The construction phase involved the installation of a sandstone-faced concrete wall along Carline Fields and the installation of demountable barriers opposite Rea Brook Terrace and adjacent to the Rea Brook itself. The new flood defences tie into a pre-existing wall at the back of Manser Antiques.

At the beginning of January 2008 the demountable sections were installed, including concrete piles topped by a re-enforced concrete beam on the highway. When Coleham Head is at risk of flooding, this concrete beam supports the demountable barriers opposite Rea Brook Terrace and adjacent to the Rea Brook itself.

The existing Coleham defences are thought to give protection to around a 1 in 50 year event. Plans are currently in place for a second flood wall to be constructed around Wakeman School, downstream of English Bridge. It is proposed to construct a 70 metre long wall, 0.5 metres high with railings on top. A gap for access to the playground will be included. Severn Trent Water Ltd may still require further pump capacity here for their sewers to prevent foul flooding.

Once these works are complete, the Coleham scheme will have a 1 in 100 year design standard. Both the existing and proposed defences have been included in this assessment.

4.5 Representation of Defences in the Model

The Frankwell defence crest levels and locations were derived from NFCDD. The built Coleham defence crest levels and locations were derived from design drawings provided by the Environment Agency (Black & Veatch, Coleham Head FAS, 'General Arrangement', Drawing No. 120419-1500-0002, Revision P0, March 2006). The proposed Coleham defence (crest level and location) was provided by the Environment Agency. Proposed ground levels were provided by Barratt Homes and the ground model revised accordingly.

Upon utilisation of the defence information in the model, it was determined that there was no crest level for the Rea Brook right embankment by Old Potts Way. The elevation was initially set the same as the elevation as Coleham Head, but this produced overtopping for the 1 in 100 year event. The embankment was subsequently surveyed and the resultant crest level utilised in the model. Again, this produced overtopping due to four low spots along the embankment (around 50.66mAOD). Upon agreement with the Environment Agency (who is looking to raise the embankment) the embankment level used in the model was the 1 in 100 year level (52.01mAOD) plus 300mm freeboard. This did not produce overtopping and brought the defence standard to 1 in 100 years.

4.6 *Breach and Overtopping Scenarios*

Flooding behind flood defences can occur as a result of constructional or operational failure of the defence, either in whole or in part (breach), or water levels rising to exceed the level of the defence (overtopping). These mechanisms can lead to rapid inundation of areas by flood water and the consequences can be potentially catastrophic.

Breaches have been carried out for the 1 in 100 year event at the following locations:

- Frankwell, upstream of Welsh Bridge (SJ 49052 12866)
- Frankwell, downstream of Welsh Bridge (SJ 48805 12784)
- Coleham (SJ 49702 12272)

In each case a failure of the defence from the top right down to the bottom has been modelled.

For the Frankwell breaches, initial modelling results indicated that the inundation was very rapid and the time steps of the model outputs were not capturing the peak velocities at the time of the breach. This resulted in an inaccurate representation of velocities adjacent to the breach location and an underestimation of the flood hazard through the affected area. The breach scenarios at Frankwell were therefore modelled in more detail using a simple 2D TUFLOW model. The existing model was trimmed to the Frankwell area. The flow over the breach was extracted from the existing model and fed into the breach location. This allowed a more detailed observation of the velocities during the breach scenario with more frequent model outputs, which enabled the peak velocities to be captured and a better representation of the flood hazard during the breach scenario.

It was not deemed necessary to model the Coleham breach in this way as the rate of inundation during the breach was slower and therefore the peak velocity and hazard were sufficiently represented.

For overtopping scenarios, a long length of the defences have been modelled during the larger return period runs (1 in 100 year plus climate change and 1 in 1000 year events).

4.7 Model QA

TUFLOW and ISIS automatically generate a list of errors, warnings and notes for each model run. A review of these messages was undertaken to assess any potential problems with the model. The messages were checked in the model and were either consistent with the model inputs or had no impact on the model results and thus no changes were required.

Difficulties were encountered when running the 1 in 1000 year event. Model runs of this nature typically result in instabilities due to the extremely large flows simulated. The model run for the 1 in 1000 year event crashed, but this occurred after the peak of the hydrograph therefore the maximum flood extent had been gained.

5 Results

5.1 *Overview*

The results of the defended model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events have been mapped, as well as the breach scenarios and these are presented in Appendix D. For each return period, the following has been produced:

- Maps showing the variation in the depth of flooding across the affected areas
- Maps showing the variation in the velocity of flooding across the affected areas
- Maps showing the variation on Flood Hazard across the affected areas
- Animations showing the rate and onset of flooding across the affected areas

This section analyses the results of the modelling and mapping outputs of the study, in order to ascertain the level of risk posed to Shrewsbury town by the range of modelled high flows and breach and overtopping scenarios.

5.2 *1 in 20 Year Event (Flood Zone 3b)*

The modelling results show that for the 1 in 20 year event the flood defences protect the Frankwell and Abbey Foregate areas, as would be expected. There are significant areas of functional floodplain, providing valuable flood storage and flood flow routes.

5.2.1 *Depth*

Upstream of Frankwell at Mountfields, an extended area of floodplain exists which is currently undeveloped. For the 1 in 20 year event, the area becomes utilised for floodplain flows and flood depths reach over 2 metres in most places. Some flooding occurs on the left bank along Coton Hill and Chester Street, though the depth is generally low (up to 50 centimetres) and reaches 90 centimetres at the most.

Downstream of Welsh Bridge flooding occurs on the left and right banks including Victoria Avenue. Flood depths immediately adjacent to the channel are high (up to 2 metres) and generally remaining at a depth of between 1 and 1.5 metres high elsewhere. This situation continues down to Kingsland Bridge.

Downstream of Kingsland Bridge, on the left bank, flood depths are generally in the order of 1 metre though there are sections of fields which store a greater depth, generally up to 2 metres. The flood extent on the right bank is minimal, though it is nonetheless deep (again up to 2 metres) including the Burr's Field are where the Rad Brook meets the River Severn.

Just upstream of Greyfriar's Bridge the flood water appears to cross onto Longden Coleham. Initially the flood depth is around 2 metres, but the water quickly shallows and although the right bank area of Coleham does flood, the depths are not significant (generally up to 50 centimetres). Around Old Coleham, however, the flood water does deepen again to around 1 metre, likely to be due to interactions with flood water from the Rea Brook.

Around English Bridge areas by Coleham Head (in front of the defences), the west of the school and the former football ground to depths of 1 to 2 metres. The area to the west of the school immediately adjacent to the channel shows the highest flood depths, in the order of 2.5 metres.

There is little other flooding until downstream of the Severn Bridge Junction, where open land either side of the channel around Underdale floods very deeply, up to 3 metres in places.

On the Rea Brook, upstream of the superstore there is flooding of natural floodplain, generally between 1 and 2 metres deep.

5.2.2 Velocity

At the Mountfields floodplain area, peak velocities are in the order of 0.6 metres per second (ms^{-1}), though in the central floodplain area and on the left bank velocities are much lower, in the order of $0.1ms^{-1}$. At the south eastern corner of the Frankwell defences, a localised high-velocity area occurs at approximately $1.1ms^{-1}$.

From Welsh Bridge to Porthill Bridge the velocities typically do not exceed $0.5ms^{-1}$. Around the area adjacent the Kingsland Bridge however, velocities reach up to $3.5ms^{-1}$ in the area adjacent to the school. Velocities around Longden Coleham are very low, around $0.1ms^{-1}$. Similarly this occurs in front of the

Coleham defences, although the area in the former football ground experiences slightly higher velocities up to $0.5ms^{-1}$. To the west of Wakeman's school and on the left bank of the River Severn, velocities are typically around $0.5\ ms^{-1}$.

Downstream of the Severn Bridge Junction, velocities are generally low, increasing downstream of Castle Bridge. The highest velocity area can be found by the weir on Sydney Avenue, where velocities reach $4ms^{-1}$. Through Underdale however, velocities are again low, rarely higher than $0.5ms^{-1}$.

Velocities along the flooded extent on the Rea Brook are very low, typically less than $0.1\ ms^{-1}$.

5.2.3 Hazard

The flood hazard map for the 1 in 20 year event shows that most of the flooded area is at moderate flood hazard, but in places it sharply increases to extreme flood hazard with little to no graduation in between.

At Mountfields the central part of the floodplain area is of moderate flood hazard, but this sharply increases to extreme flood hazard with proximity to the River Severn, and on the western side. Flooding on the left bank is generally of low to moderate hazard. Overall, this area is shown to have an abundance of deep and fast flowing water which contributes to the extreme hazard, confirming the requirement to keep this area as undeveloped functional floodplain.

The flooded area in front of the Frankwell defences is generally of significant to extreme hazard. From Welsh Bridge to Greyfriars Bridge the flooded area generally exhibits moderate flood hazard, but with extreme flood hazard with proximity to the channel. At Coleham there is a localised area displaying extreme flood hazard.

Flooding at Longden Coleham is of low to moderate hazard, as is generally experienced around the English Bridge area. Downstream of English Bridge there are pockets of extreme flood hazard, which again contrast sharply to the moderate hazard exhibited elsewhere in the area. The extreme flood hazard resumes downstream of the weir along Sydney Avenue.

The flooded area along the Rea Brook is substantially moderate flood hazard, though there are small pockets of extreme flood hazard exhibited in areas immediately adjacent to the channel.

5.3 *1 in 100 Year Event (Flood Zone 3a)*

The modelling results show that the 1 in 100 year extent is generally not significantly larger than the 1 in 20 flood extent, with the exception of the area along the right bank of the Bagley Brook between Mountpleasant and Spring Gardens where a significant number of additional areas are shown to be affected by flooding. In most places, the depth, velocity and hazard increase between the 1 in 20 and 1 in 100 year event. The flood defences protecting the Frankwell area do not overtop, and while this is also the case at Abbey Foregate, there is a slightly larger flood extent. As with the 1 in 20 year event, there are significant areas of functional floodplain, providing valuable flood storage and flood flow routes.

5.3.1 *Depth*

In comparison to the 1 in 20 year event, flood depths for the 1 in 100 year event appear to increase quite significantly. Upstream of Frankwell at Mountfields, the depth of flooding in the extended area of floodplain is in excess of 2.5 metres in most places. Further downstream, the depth of flooding on the left bank along Coton Hill and Chester Street also increases significantly, reaching depths of over 3 meters in some places, particularly the areas adjacent to the watercourse and towards Gravel Hill Farm.

Downstream of Welsh Bridge the depth of flooding on the left and right banks and Victoria Avenue increases by approximately 0.5 metres in comparison to the 1 in 20 year event. Flood depths immediately adjacent to the channel are again high (up to approximately 2.5 to 3 metres), and generally remain between 1.5 and 2 metres elsewhere.

Downstream of Kingsland Bridge, the extent and depth of flooding on the left bank is greater for the 1 in 100 year event, ranging between 1.5 and 3 meters. On the right bank, the extent of flooding is again minimal with only the areas immediately adjacent to the channel being affected. Here however the depth of flooding is significant, reaching up to 3 meters. At Burr's Field, the depth of flooding increases by approximately 70cm between the 1 in 20 year and the 1 in 100 year event.

Upstream of Greyfriar's Bridge where the flood water crosses onto Longden Coleham, the extent of flooding increases slightly between the 1 in 20 and 1 in 100 year event, affecting Pound Close, Moreton Crescent and Old Coleham. Adjacent to the watercourse, the depth of flooding is approximately 50cm greater than the 1 in 20 year event although the as with the 1 in 20 year event the water shallows on the right bank, before deepening around Old Coleham to around 1.5 metres.

Downstream of English Bridge, the extent of flooding is generally similar to the 1 in 20 year event, affecting the same areas of floodplain; however, the depth is greater, at around 1.5 to 3.0 metres around English Bridge, Coleham Head and to the west of the school. Downstream of the Severn Bridge Junction, again there is little flooding on the left bank, with some flooding on the right bank, reaching depths of between 1 and 3 metres. Within the open land either side of the channel around Underdale, depths increase by approximately 50cm between the 1 in 20 and 1 in 100 year event, peaking at around 2.0 and 2.5 metres.

Along the Rea Brook, the extent of flooding of the natural floodplain increases slightly between the 1 in 20 and 1 in 100 year events to depths of between 1.5 and 2.5 metres. During the 1 in 100 year event the area adjacent to the superstore is now affected during the 1 in 100 year event, although the depths are generally shallow, being less than 50cm.

5.3.2 *Velocity*

In general, there is little difference in floodplain velocities between the 1 in 20 year and 1 in 100 year events. At Mountfields, velocities generally peak around 1.0ms^{-1} with the central floodplain velocities remaining low, at 0.2ms^{-1}. At the south eastern corner of the Frankwell defences, the velocity increases by only 0.3ms^{-1} (to 1.4ms^{-1}) for the 1 in 100 year event.

Between Welsh Bridge and Greyfriars Bridge, floodplain velocities are generally low, typically not exceeding 0.6ms^{-1}. Immediately upstream of Kingsland Bridge, velocities increase to around 2.0ms^{-1}. For the area adjacent to Kingsland Bridge velocities can be higher, reaching nearly 6ms^{-1} in area to the west of the school as floodplain flows are restricted through the bridge. Velocities around Longden Coleham are similar to the 1 in 20 year event, typically being less than 0.1ms^{-1}. Adjacent to Wakeman's School and on the left bank of the River Severn, although velocities are higher for the 1 in 100 year event, the difference is minimal with velocities generally being less than 0.5ms^{-1}.

Downstream of Severn Bridge Junction, velocities are slightly higher for the 1 in 100 year event with the highest velocities again occurring around Sydney Avenue, reaching up to 6ms^{-1}. Through Underdale however, velocities are generally low, rarely exceeding 0.5ms^{-1}.

5.3.3 *Hazard*

The flood hazard map for the 1 in 100 year brings more areas into the extreme hazard classification, compared to the 1 in 20 year event, with the majority of the modelled area classified with a moderate to extreme hazard. As with the 1 in 20 year event, there is little or no graduation between the areas shown to be at a moderate and extreme flood hazard.

Towards the upper part of the modelled area around Coton Hill, the flood hazard is predominantly moderate, increasing to extreme in some areas adjacent to the channel and Berwick Road between the 1 in 20 year and 1 in 100 year event. At Mountfields only a small part of the central floodplain area is of moderate flood hazard, with the remaining area classified as extreme flood hazard. As with the 1 in 20 year event, this area is shown to have an abundance of deep and fast flowing water which contributes to the extreme hazard, confirming the requirement to keep this area as undeveloped functional floodplain.

Along the left bank of the River Severn, the flood hazard is classified as low to moderate around the A468 (Coton Hill and Chester Street). This continues further downstream, with the flooded area opposite Frankwell also exhibiting a low to moderate flood hazard, with only a small part of the floodplain adjacent to the channel classified with an extreme flood hazard.

Between Welsh Bridge and Greyfriars Bridge the flooded area exhibits a predominantly extreme flood hazard, with only a small part of the floodplain showing a moderate to significant hazard in the areas furthest away from the channel.

Downstream of Kingsland Bridge, the area forming the playing fields on the left bank between Crescent Lane and Greyfriars Bridge show a moderate to extreme hazard during the 1 in 100 year event, with the area classified with an extreme hazard being significantly greater than for the 1 in 20 year event. Between Greyfriars Bridge and Severn Junction, the affected area on the left bank shows a predominantly low to moderate hazard with the exception of a small area adjacent to the Government Office where the flood hazard is significant to extreme. On the right bank, the flood hazard remains low to moderate for the 1 in 100 year event within the areas around Longden Coleham and Coleham Head.

Downstream of English Bridge past Wakeman's School through to Underdale, the areas of floodplain affected by the 1 in 100 year event exhibit a predominantly moderate to extreme flood hazard, with the areas immediately adjacent to the channel showing the greatest hazard. The areas furthest away from the channel show a lower hazard, particularly on the left bank through Ditherington, where the hazard is classified as low to moderate for much of the affected area.

Along the Rea Brook, the flooded area shows a predominantly moderate flood hazard, although the area of natural floodplain upstream of the superstore exhibits a relatively large area of extreme hazard demonstrating the need to protect the natural floodplain from future development.

5.4 *1 in 100 Year Event plus Climate Change (Flood Zone 3a +20%)*

The modelling results show that the 1 in 100 year climate change flood extent is generally similar to the 1 in 100 year event, with some areas showing a greater extent including the area on the right bank of the Bagley Brook between Mount Pleasant and Spring Gardens, the area along Longden Coleham, and the area to the west of Sydney Avenue around Tarvin Road, Tilbrook Avenue, Avondale Drive and Regents Drive.

Both the flood defences at Frankwell and Coleham overtop during the 1 in 100 year climate change event, with a significant number of properties affected, particularly in the Frankwell and Abbey Foregate areas. The maps in Appendix D show the area of inundation as a result of the defences overtopping.

5.4.1 *Depth*

In many locations, the depth of flooding increases by approximately 50 to 70cm between the 1 in 100 and 1 in 100 year climate change event. At Mountfields, an increase of approximately 70cm is shown, with depths over 3.0 metres in places. On the left bank around Coton Hill and Chester Street, both the extent and depth of flooding increases for the 100 year climate change event to depths of between 2.5 and 3.0 metres in most locations. Immediately adjacent to the watercourse depths of up to 4.0 metres occur.

Behind the flood defence at Frankwell, flood water reaches in excess of 3.0 metres in the areas immediately adjacent to the defence, becoming shallower further away from the defence, where depths are typically less than 1 metre. To the west of the Frankwell defence, depths range between 2.0 to 2.5metres. On the left bank opposite Frankwell, the depth of flooding increases by up to 80cm between the 1 in 100 year and the 1 in 100 year climate change event, typically reaching between 0.5 and 2.0 metres.

Downstream of Welsh Bridge, the depth of flooding on the left and right banks and the area along Victoria Avenue increases by approximately 70cm., with depths in the areas immediately adjacent to the channel reaching up to 3 metres.

Within the Coleham area upstream of Greyfriars Bridge, the 1 in 100 year climate change flood extent is generally similar to 20 and 100 year events, however the depth of flooding increases by approximately 70cm to between 2 to 3 metres. On the right bank, again the extent of flooding is minimal for the 100 year climate change event, although the depth of flooding can be up to 3 metres. At Burr's Field the depth of flooding increases by approximately 50 to 60 cm between the 1 in 100 and the 1 in 100 year climate change event. At Longden Coleham the extent of flooding increases significantly for the 1 in 100 year climate change event, affecting more properties along Greyfriars Road, Pound Close and Moreton Crescent. Depths tend to be greatest in the area closest to the watercourse, (between 1.5 and 2.0 metres); becoming shallower further from the watercourse (approximately 0.5 metres).

At Coleham, the flood defences overtop during the 1 in 100 year climate change event, affecting a large part of the Old Coleham and Abbey Foregate area. To the west of the railway line, floodwater is deep, typically 2.5 metres. Further to the east, water remains deep (approximately 2.5 metres), becoming shallower to the east of the Abbey itself and along the right bank of the River Rea where depths are typically less than 1.0 metre).

Downstream of English Bridge, the extent of flooding around English Bridge and to the west of the school is similar to the 1 in 100 year event, affecting only a marginally greater extent of the floodplain, with depths increasing by 60cm between the 1 in 100 and 1 in 100 year climate change events. Downstream of the Severn Bridge Junction, the extent of flooding on the left bank is similar to lower modelled events, with depths increasing by about 50cm. The depth of flooding to the open land on the right bank of the channel around Underdale increases by approximately 50cm for the 1 in 100 year climate change event.

On the left bank of the River Severn adjacent to Sydney Avenue, the extent of flooding increases significantly between the 1 in 100 year and the 1 in 100 year climate change event. In the area adjacent to the channel within the recreation gardens, the depths range between 2.5 and 3.5 metres, becoming shallower (typically less than 0.5 metres) in the more urban area the west of Sydney Avenue.

On the Rea Brook, the extent of flooding increases slightly for the 1 in 100 year climate change event, reaching up to 3.0 metres on the right bank upstream of the superstore in the natural floodplain area. Depths become shallower further from the channel around the edge of the natural floodplain storage area, generally being less than 1.5 metres. On the left bank, the area adjacent to the superstore floods to a greater extent during a 1 in 100 year climate change event, although the depth of flooding is less than 1.5metres.

5.4.2 *Velocity*

In general, the velocities for the 1 in 100 year climate change are similar to those of the 1 in 20 year and 1 in 100 year events around Mountfields, peaking at around 0.9ms^{-1}. At the south eastern corner of the Frankwell defences, the velocity is slightly higher, reaching peak velocities of approximately 1.4ms^{-1}.

The Frankwell defences overtop during the 1 in 100 year climate change event. Here, velocities are typically low, being less than 0.1ms^{-1} with the exception of a thin part of the centre of the affected area from the car park at Mountfields to Frankwell where velocities are generally higher reaching up to 1.3ms^{-1} in places.

Between Welsh Bridge and Greyfriars Bridge, floodplain velocities remain low, rarely exceeding 0.7ms^{-1}. In some locations the velocities for the 1 in 100 year climate change event are lower than the 1 in 100 year event. In the area adjacent to Kingsland Bridge, velocities reach up to 3ms^{-1}. This is lower than the velocities experienced during the 1 in 20 year and 1 in 100 year at this location (4ms^{-1} and 8ms^{-1} respectively). On the left bank of the River Severn upstream of English Bridge, velocities are generally low, being less that 1ms^{-1}.

Velocities around Longden Coleham remain relatively low for the 100 year climate change event, generally not exceeding 1.0ms^{-1}. Towards Moreton Crescent and Old Coleham however, the velocities increase, ranging between 1.0ms^{-1} and 2.0ms^{-1}. Along Coleham Road, velocities peak at just over 3.0ms^{-1} in places.

Within the Abbey Foregate area velocities are generally low (less than 0.20ms-1), although the area adjacent to the railway demonstrates slightly higher velocities of around 0.70ms^{-1}.

Within the area adjacent to Wakeman's School downstream of English Bridge, and the left bank of the River Severn, velocities are typically less than $1.0ms^{-1}$, being higher in the area immediately adjacent to the channel. Downstream of Severn Bridge Junction, velocities on the right bank reach up to $0.6ms^{-1}$ and approximately $0.2ms^{-1}$ on the left bank. Downstream of Castle Bridge, velocities on both the left and right banks increase to between 1.0 and $2.0ms^{-1}$. These slightly higher velocities increase further downstream of the weir at Sydney Avenue, particularly in the areas adjacent to the channel where peak velocities of up to $7.0ms^{-1}$ are experienced on the left bank. Through Underlade, velocities tend to be slightly lower, particularly in the more urban areas further away from the channel where velocities rarely increase to above $0.20ms^{-1}$.

5.4.3 Hazard

The flood hazard map for the 1 in 100 year climate change event shows the majority of areas to be classified with an extreme flood hazard, with only a few areas demonstrating a low to moderate flood hazard. As with the 1 in 20 and 1 in 100 year events, there is little graduation between the areas shown to be at a moderate and extreme flood hazard.

At Mountfields, the flood hazard is classified as extreme, with only a small part of the central floodplain demonstrating a moderate to significant flood hazard. Further downstream, the flood hazard within the area on the left bank of the River Severn opposite Frankwell increases to a moderate to significant flood hazard for the 100 year climate change event, with only a few areas demonstrating a low hazard. Within the area immediately adjacent to the watercourse, the flood hazard increases to extreme for the 100 year climate change event.

Behind the flood defence at Frankwell upstream of English Bridge, the flood hazard is generally low to moderate, increasing to a significant to extreme in the area through the centre of the affect area through the car park and along Frankwell and, in the far eastern corner of the affected area immediately adjacent to the watercourse.

Between Welsh Bridge and Greyfriars Bridge the flooded area generally exhibits an extreme flood hazard in most areas, with only a small part of the floodplain further away from the channel showing a moderate to significant hazard.

At Coleham, the flood hazard increase within the area on the left bank with more areas demonstrating an extreme hazard. The area on the left bank immediately upstream of the English Bridge area increases to a predominantly moderate flood hazard with some small areas showing a low hazard. At Longden Coleham, although the extent of flooding is greater for the 100 year climate change event, the flood hazard remains at a low to moderate hazard, increasing to a significant to extreme hazard the further east you move along Longden Coleham and Old Coleham. Downstream of the English Bridge area, the flood hazard is typically moderate to extreme.

At Underdale, the flood extent for the 100 year climate change event is significantly greater than the 1 in 100 year event. For the area adjacent to the channel and through the recreation gardens, the flood hazard is typically extreme. Further away from the channel in the more urban areas and towards Ditherington the flood hazard is predominantly moderate.

The flooded area along the Rea Brook shows a predominantly extreme flood hazard within the floodplain area adjacent to the watercourse, decreasing to a moderate hazard in the areas further away from the watercourse. Only a small part of the affected area shows a low flood hazard at the furthest point away from the channel. Within the affected area at Abbey Foregate, the flood hazard is extreme in the area immediately adjacent to the watercourse, decreasing to moderate for the remaining area. Again, only a small part of the affected area demonstrates a low hazard.

5.5 1 in 1000 Year Event (Flood Zone 2)

Modelling results indicate that in general, there is not a significant difference in the extent of the 1 in 100 year climate change event and the 1 in 1000 year event. Minor differences are evident on the right bank of the River Severn opposite Frankwell, and on the right bank within the Coleham area upstream of Greyfriar's Bridge. Further downstream, more significant differences can be found in the flood extent with a greater portion of the floodplain utilised in the sportsfield downstream of Severn Bridge Junction, and in the area on the left bank of the River Severn downstream of the weir at Sydney Avenue.

5.5.1 Depth

The depth of flooding in the Mountfields area increases by approximately 40cm between the 1 in 100 year climate change and the 1 in 1000 year event, with maximum depths of up to 4.0 metres. On the left bank around Coton Hill and Chester Street, depths also increase by approximately 40cm, reaching between 2.0

and 2.5 metres. Immediately adjacent to the watercourse depths of over 4.5metres occur.

Behind the Frankwell defences, the depth of flooding increases by approximately 30 to 50cm between the 1 in 100 year climate change and the 1 in 1000 year event. As with the climate change scenario, the deepest flooding occurs through the centre of the affected area and in the area immediately behind the defences. On the left bank of the River Severn opposite the Frankwell area, a greater extent of flooding occurs with depths upstream of Welsh Bridge typically reaching 2.0 to 2.5metres. Downstream of Welsh Bridge, floodwaters are shallower, generally being less than 1.0metre.

Between Welsh Bridge and Kingsland Bridge the depth of flooding increases by approximately 50cm during the 1 in 1000 year event, to between 2.5 and 3.0metres, becoming slightly deeper towards Kingsland Bridge. On the right bank, there is little difference in the extent of flooding between the modelled events, with depth of flooding typically between 2.5 and 3.0 metres for the 1 in 1000 year event. At Burr's Field, depths are approximately 3.0 to 3.5metres.

At Coleham, the extent of flooding on the left bank upstream of Greyfriars Bridge is again similar to the other modelled events, with depths increasing by approximately 50cm during the 1 in 1000 year event reaching approximately 3.0 to 4.0 metres. On the right bank, again the extent of flooding is minimal, differing very little from the 1 in 100 year climate change event. Depths are however slightly greater here, being up to 60cm deeper. At Burr's field, the depth of flooding increases by approximately 50cm between the 100 year climate change and the 1000 year event, with maximum depths of around 3.8metres.

As with the 1 in 100 year climate change event the defences at Coleham overtop during the 1 in 1000 year event. A large part of the Abbey Foregate area is affected with depths reaching up to 3.0metres adjacent to the defence to the west of the railway line. Further to the east of the railway line, water remains deep (approximately 2.5 metres), becoming shallower to the east of the Abbey itself and along the right bank of the River Rea where depths are typically less than 1.0 metre).

Within the Coleham area upstream of Greyfriars Bridge, the 1 in 1000 year flood extent is similar to the 1 in 100 year climate change with depths being approximately 50cm greater (2.5 to 3.0metres). On the right bank at Longden

Coleham, the extent of flooding is slightly greater for the 1 in 1000 year event, although the depth is only marginally different to the 1 in 100 year climate change event, generally being between 10 to 30cm deeper (approximately 1.0 to 2.5metres).

Downstream of English Bridge, the extent of flooding within the former football ground and the area to the west of the school is greater for the 1 in 1000 year event. Adjacent to the channel, the depth of flooding is greater (around 3.0 to 4.0metres), becoming shallower further east (less than 0.1metres). Downstream of Severn Bridge Junction, the extent of flooding on the left bank is minimal, with depths of approximately 2.5 to 3.0metres. On the right bank however, the extent of flooding increases significantly for the 1 in 1000 year event, with depths of approximately 3.5metres in the area adjacent to the channel, becoming shallower (less than 1.0metre) further away from the channel.

Through Underdale, flooding is generally restricted to the left bank during the 1 in 1000 year event, with depths reaching up to 4.0metres in the area immediately adjacent to the channel, becoming shallower in the areas further away from the channel (typically less than 1metre).

Along the Rea Brook, the extent of flooding increases marginally between the 1 in 100 year climate change and the 1 in 1000 year flood event. On the right bank upstream of the superstore, depths reach up to 4.0metres in the natural floodplain area. In the areas further away from the channel depths become shallower, generally being less than 1.5metres. On the left bank within the superstore car park, the depth of flooding ranges between 10. to 2.0metres for the 1 in 1000 year event.

5.5.2 *Velocity*

Modelling results indicate that there is little difference between the velocities for the 1 in 1000 year and the 1 in 100 year climate change event. At Mountfields, velocities are typically 0.4ms^{-1} throughout the majority of the affected area, peaking at around just over 0.8ms^{-1} towards the top of the affected area. As with the other modelled events, velocities are slightly higher, reaching peak velocities of approximately 1.3ms^{-1}. This is slightly lower than the velocities experienced for the 1 in 100 year climate change event (1.4ms^{-1}).

In the area behind the Frankwell defences, the extent of flooding during the 1 in 1000 year event is similar to the 1 in 100 year climate change event, however the velocity is slightly greater, peaking at around 1.6ms^{-1}. As with the other modelled scenarios, the area through the centre of the site and immediately behind the defences experiences the greatest velocity.

Between Welsh Bridge and Greyfriars Bridge, floodplain velocities remain low, increasing by approximately 0.04ms^{-1} between the 1 in 100 year climate change and the 1 in 1000 year event. Velocities typically range between 0.6 and 0.8ms^{-1} through the majority of the affected area, increasing to a peak of approximately 1.8ms^{-1} at Kingsland Bridge. In the Coleham area upstream of English Bridge, the velocity remains low for the 1 in 1000 year event, typically being less than 0.3ms^{-1}.

At Longden Coleham, velocities remain low for the 1000 year event, generally not exceeding 0.5ms^{-1} in the majority of areas. Further towards Old Coleham and Coleham head, velocities increase, peaking at around 2.0 to 2.5ms^{-1}.

Within the Abbey Foregate area, the defences overtop during the 1 in 1000 year event. Here, velocities are generally low (less than 0.20ms^{-1}), although the area adjacent to the railway demonstrates slightly higher velocities of up to approximately 1.2ms^{-1}.

Within the area adjacent to Wakeman's School downstream of English Bridge, velocities for the 1 in 1000 year event, velocities are similar to the other modelled events, being less than 1.0ms^{-1} in the majority of places. A similar situation is found on the left bank of the River Severn where velocities are generally 0.5 to 1.0ms^{-1} in the 1 in 1000 year event.

Downstream of Severn Junction, the extent of flooding for the 1 in 1000 year event is greater than for the 1 in 100 year climate change event. Velocities in the affected area are generally low, being less than 0.5ms^{-1} in the majority of areas. In the area adjacent to the channel, velocities are slightly higher, particularly in the area around the weir at Sydney Avenue where peak velocities of up to 6.0ms^{-1} are experienced on the left bank. This is slightly lower than those for the 1 in 100 year climate change event where velocities of up to 7.0ms^{-1} are experienced.

As with the other modelled events, the velocities for the 1 in 1000 year event through Underlade tend to be highest in the areas adjacent to the watercourse (up to 0.8ms^{-1}), but decrease at distances further away from the watercourse to velocities typically less than 0.5ms^{-1}. In the floodplain area between the 1 in 100 year climate change and the 1 in 1000 year climate change, the velocities tend to be low (less than $0.3ms^{-1}$).

5.5.3 *Hazard*

The flood hazard map for the 1 in 1000 year event shows the majority of areas to be classified with an extreme flood hazard. As with the other modelled events, there is little graduation between the areas shown to be at a moderate and extreme flood hazard.

At Mountfields, the flood hazard is classified as extreme for the majority of the affected area with only a small part of the central floodplain demonstrating a moderate to significant flood hazard. On the left bank of the River Severn opposite Frankwell, the flood hazard is classified as low to moderate, increasing to an extreme hazard in the area adjacent to the River channel.

Downstream of Welsh Bridge, the flood hazard between the 1 in 100 year climate change and the 1 in 1000 year event is generally similar only increasing slightly. The area furthest from the channel remains at a low to moderate hazard for the 1000 year event. Within the area behind the Frankwell defence upstream of Welsh Bridge, the flood hazard increases significantly between the 1 in 100 year and 1000 year climate change event with a greater area classified with an extreme hazard.

Between Welsh Bridge and Greyfriars Bridge the flooded area generally exhibits an extreme flood hazard in most areas, with only a small part of the floodplain further away from the channel showing a moderate to significant hazard.

At Coleham, the flood hazard on the left bank increases slightly between the 100 year climate change and the 1000 year event with a greater area showing an extreme hazard. In the area immediately upstream of English Bridge, the flood hazard is predominantly moderate with some areas demonstrating an extreme flood hazard at isolated locations. Where the Coleham defence is overtopped during the 1 in 1000 year event, the flood hazard within the Abbey Foregate area is generally high in the area adjacent to the defence and to the west of the railway. To the east of the railway, the flood hazard is also predominantly high, decreasing to a predominantly moderate hazard to the east of the Abbey itself.

Downstream of English Bridge, the flood hazard is classified as extreme in the area adjacent to the watercourse and within the former football ground. To the east of the former football ground, the flood hazard is lower, being classified as predominantly low to moderate.

Downstream of Severn Bridge Junction, the area affected by flooding during the 1 in 1000year event is generally classified with a low to moderate flood hazard. Within the floodplain immediately adjacent to the watercourse however the flood hazard is classified as extreme.

At Underdale, the flood extent for the 1000 year event is significantly greater than the 1 in 100 year climate change event. For the area adjacent to the channel and through the recreation gardens, the flood hazard is typically extreme. Further away from the channel in the more urban areas and towards Ditherington the flood hazard is predominantly moderate with some areas with a low flood hazard in the areas furthest from the watercourse.

The flooded area along the Rea Brook shows a predominantly extreme flood hazard within the floodplain adjacent to the watercourse, decreasing to a moderate hazard in the areas further away from the watercourse. Only a small part of the affected area shows a low flood hazard at the furthest point away from the channel. Within the affected area at Abbey Foregate, the flood hazard is extreme in the area immediately adjacent to the watercourse, decreasing to moderate for the remaining area. Again, only a small part of the affected area demonstrates a low hazard.

5.6 Frankwell Breach Scenarios

With a breach applied to the Frankwell defence upstream of Welsh Bridge, the area behind the defence is shown to be affected by flooding with a significant number of properties affected. With a breach applied to the defence downstream of Welsh Bridge, the extent of flooding is marginally smaller than the scenario with a breach applied upstream of the bridge. In both cases, the extent of flooding is not as great as the 1 in 100 year climate change scenario when the defence is overtopped.

5.6.1 Depth

The depth of flooding behind the defence with a breach applied upstream of Welsh Bridge is greatest towards the eastern part of the affected area, reaching up to 2.6metres in the area immediately behind the defence. Across the remainder of the site, the depth of flooding is typically less than 2.0metres, with the exception of the south western corner behind the defence where depths reach up to 2.4metres.

With a breach applied to the Frankwell defence downstream of Welsh Bridge, the depth of flooding is generally less than 2.0metres across the affected parts of the site. Within the area immediately adjacent to the breach, depths reach up to 2.3metres. In comparison to the breach scenario upstream of Welsh Bridge, the depth of flooding is approximately 35cm shallower across the affected area.

5.6.2 *Velocity*

With a breach applied to Frankwell defence upstream of Welsh Bridge, the velocity is greatest in the area immediately adjacent to the defence. At the start of the breach scenario, the velocity is high through the breach area, typically being greater than 2.0ms^{-1}. Throughout the majority of the site, velocities range between 1.4 and 2.0ms^{-1}, reaching up to 3ms^{-1} in places in the time period immediately after the breach. As the water spreads through the affected area, water ponds behind the defence and velocities become much slower (less than 0.01ms^{-1}).

Modelling results are similar with a breach applied to the Frankwell defence downstream of Welsh Bridge, with velocities being highest around the breach location. The peak velocity is approximately 1.8 to 1.9ms^{-1}, with velocities through the remainder of the affected area generally ranging between 1.2 and 1.5ms^{-1}. As with the breach scenario upstream of Welsh Bridge, as water spreads through the affected area, water ponds behind the defence and velocities become much slower (less than 0.01ms^{-1}).

5.6.3 *Hazard*

Model results indicate that with a breach applied to the Frankwell defence upstream of Welsh Bridge, the flood hazard is greatest in the area adjacent to the breach and to the north of the site (classified as extreme), with the majority of the affected area classified with a significant flood hazard (danger for all). Only a small part of the affected area demonstrates a low flood hazard (danger for some) at isolated locations.

With a breach applied to the Frankwell defence downstream of Welsh Bridge, the flood hazard is predominantly significant with only the area immediately adjacent to the breach location classified as extreme (danger for all). To the east of the breach location, the flood hazard is generally significant, with some areas showing a low to moderate flood hazard.

5.7 Coleham Breach Scenario

With a breach applied to the defence at Coleham, the modelling results demonstrate that a substantial amount of the Abbey Foregate area is affected by flooding.

5.7.1 *Depth*

The modelling results demonstrate that with a breach applied at Coleham, flooding to the Abbey Foregate area reaches depths of up to about 1.5metres. In the area immediately adjacent to the breach, along Coleham Head, the depth of flooding is greatest, becoming shallower to the east of the railway line where depths are generally less than 0.50metres. The depth of flooding during the breach scenario is less (approximately 1.0metre) than for the 1 in 100 year climate change event when the Coleham defences overtop along their extent.

5.7.2 *Velocity*

Modelling results indicate that velocities across the affected part of the site are generally low (less than $0.50ms^{-1}$) when a breach is applied to the Coleham defence. Modelling has also indicated that the rate of inundation is slow throughout the breach scenario.

5.7.3 *Hazard*

With a breach applied to Coleham defence, the flood hazard is generally significant (danger for all) across the majority of the affected parts of the site. To the east of the railway, in the area adjacent to the Abbey, a small part of the affected area demonstrates a low to moderate flood hazard with danger for some.

5.8 Conclusions

Overall the Level 2 SFRA hydraulic modelling has demonstrated that there are significant variations in flood hazard, both within the same return period and between different return periods, demonstrating that the hazard posed when an event occurs will not be uniform across the flooded area. The modelling has also demonstrated that the Frankwell and Coleham defences (which include proposed defences) have a design standard of 1 in 100 years, but are both overtopped for the 100 year plus climate change event and the 1 in 1000 year event. The performance of the existing Coleham defences only has not been assessed. The breach scenarios at Frankwell have demonstrated that if a breach occurred during the 1 in 100 year event, inundation would be rapid, with fast, deep waters producing areas of extreme flood hazard. The area of inundation would be equal to if the defence wasn't there. At Coleham, a defence breach would cause slower inundation, with lower velocities and depths, but still hazardous nonetheless. Chapter 6 uses these modelling results to put forward suggested flood risk management policies for Shrewsbury.

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6 Policy Recommendations

6.1 *Overview*

This chapter provides recommendations to enhance the existing flood risk management policies outlined in the Level 1 SFRA report. The recommended policies provided are intended to be locationally specific.

This chapter also provides Development Control policies and guidance for development in different flood zones, which can be used by potential developers required to produce site-specific FRAs, and to help the Council deal with non-allocated 'windfall' sites.

The following recommendations are in line with PPS25 and are in accordance with the broad objectives of the 'Middle Severn' Policy Unit from the River Severn CFMP.

6.2 *Flood Risk Suitability Assessment Criteria*

Each of the Council's potential land allocations which fall in the modelled study area have been assessed in Appendix B, where individual recommendations for each site are put forwards, in line with Sequential Testing requirements.

PPS25 should not be applied in isolation but as part of the planning process. The formulation of Council policy and the allocation of land for future development must also meet the requirements of other planning policy, and it is recognised that flood risk forms just one material planning considerations among many. To assist the Council in assessing flood risk issues in conjunction with other planning considerations, each site has been assigned with a 'suitability' ranking, outlined in Table 6. Section 6.3 below summarises the findings of this assessment.

Table 6: Flood Risk Suitability Assessment Criteria

Scoring Code	Criteria Definition
1	Site is mainly in Flood Zone 3b
2	Site is mainly in Flood Zone 3a
3	Site is mainly in Flood Zone 2
4	Site is mainly in Flood Zone 1 but affected by Flood Zones 2, 3a and 3b
5	Site is fully in Flood Zone 1

It should be noted that historical flooding, flood risk from other sources and residual risk has also been incorporated into the suitability assessment.

6.3 Planning Recommendations for the Potential Development Sites

Each of the Council's potential land allocations which fall in the modelled study area have been assessed in Appendix B, where individual recommendations for each site are put forwards, in line with Sequential Testing requirements. This section summarises those recommendations.

The majority of potential development sites along the River Severn through Shrewsbury are affected by fluvial flood risk in some form. Only four sites are shown to lie fully within Flood Zone 1 (Sites **160** and **SH52, SH76A**, **SH55**). For these sites, any type of development is deemed suitable provided the guidance for development in Flood Zone 1 is followed.

Seven proposed development sites are located along the Bagley Brook section of the River Severn (Sites **2**, **86**, **118**, **254**, **298**, **SH22** and **SH57**). These sites lie between two branches of the railway line and flood risk is exacerbated by the presence of the railway, with Flood Zone maps indicating that water backs-up behind the structure which acts as an informal flood defence barrier to floodplain flow. It is recommended that the Council liaise with Network Rail to ascertain the future maintenance and use of the railway embankment. In addition, an FRA for all sites within the vicinity of the railway culvert should consider the residual risk of an increase in flood hazard should the railway culvert become blocked or collapse.

Sites **2**, **86, SH22** and **SH57**, lie on the left bank of the Bagley Brook. Site **SH57** lies fully within Flood Zone 3a with just over half of the site located within Flood Zone 3b. Modelling undertaken as part of this study has indicated that sites **2**, **86** and **SH22** lie fully in Flood Zone 3a. It should be noted that for sites **86** and **SH22,** Flood Zone 3b for Bagley Brook, gathered from the Environment Agency for the Shropshire Level 1 SFRA, indicates that these sites lie almost fully in Flood Zone 3b. However, modelling undertaken as part of this commission indicates that these sites are not in Flood Zone 3b. It is assumed that there has been a manual adjustment to the Environment Agency's Flood Zone 3b in this area and therefore the sites have been assessed as if lying fully in Flood Zone 3b. Table D3 of PPS25 states that housing is not permitted in Flood Zone 3b and must pass the Exception Test for development in Flood Zone 3a. The flood hazard across these sites is predominantly moderate, with some small pockets of extreme flood hazard across sites **86** and **SH57** for the 1 in 1000 year event. Given the degree of flood risk posed across these sites, and the moderate flood hazard for the range of modelled events, it is strongly recommended that alternative sites in lower risk flood zones are considered in preference.

Modelling has indicated that although sites **118** and **254** are not located immediately adjacent to the watercourse, they are substantially affected by Flood Zone 2. With climate change, more frequent flooding of the site is also expected and modelling has indicated that this will lead to an increase in the flood hazard to extreme (danger for all). Alternative sites located fully in Flood Zone 1 should therefore be considered in preference to these sites.

Site **298** is deemed suitable for development provided that the flood risk areas to the north of the site remain as open space. For this site however, it is essential that safe access and egress for the 100 year plus climate change event is ensured should vulnerable development uses be proposed for this site. The A528 (Ellesmere Road) is the only route into the site and during the 100 year climate change event the road is flooded to both the north and south of the site. To the north of the site, modelling has indicated floodwaters across the road will be deep (approximately 2metres), which may make access and egress difficult during the 100 year climate change event. To the south of the site, the average depth of water across the road is shallower (less than 0.5metres). Access / egress may therefore be possible to the south, however, it may be necessary to ensure that road raising works are undertaken as part of this development.

Two potential development sites are located to the east of the railway line that runs adjacent to the Bagley Brook (Sites **SH55** and **SH76A**). For both of these sites, the fluvial flood risk is low with both sites lying fully within Flood Zone 1. Any type of development is therefore suitable for these sites provided the relevant guidance for development in Flood Zone 1 is considered. The FRA for these sites will however require a detailed assessment of the railway embankment's ability to hold back water, in line with the requirements set out in paragraph 7.16 of the PPS25 Practice Guide (2008).

For site **SH55**, a drain is located within the south eastern corner of the site. A development easement for development from the top of the bank of the drain should be negotiated with the EA (typically 8m), and the potential residual risk arising from a blockage of the culvert to the south of the site should be assessed as part of an FRA.

6.4 Policy Recommendations for Shrewsbury

Important flood flow routes and high-hazard informal flood storage areas have been identified through Shrewsbury. These areas must be safeguarded from future development, and maintained and operated as such (by the Council). This discounts the feasibility of site **1** for development where much of the site is located within Flood Zones 2 and 3a. However, should the Sequential Test indicate that this site is required for development, the exception Test will need to demonstrate that there are no other reasonably available site in areas of lower flood risk. If it is subsequently deemed necessary for development to proceed, compensatory flood storage will be required and assessed as part of an FRA to ensure that a positive gain in floodplain storage capacity is provided on-site and that there are no negative impacts on flood conveyance routes. Since the flood hazard is low across the affected parts of site **1**, it should be possible for all flood events to be adequately mitigated against through raised floors and flood resistance and resilience measures. The site should also be developed sequentially, with the most vulnerable aspects of the development (housing) directed towards the north of the site by Abbey Foregate Road, which lies fully in Flood Zone 1.

There is residual risk posed to the area behind the Frankwell defences, should the defences breach or overtop. Modelling has demonstrated that during a breach scenario, the area immediately behind the defence is at the greatest risk, particularly around the breach location, where the onset of flooding is rapid and no warning of occurrence. Flood water is also deep throughout the majority of the affected area. Further, the defences are shown to overtop for a 1 in 100 year plus climate change event, with similar effects. This demonstrates that development behind the defence would be very susceptible to flood risk as a result of climate change, indicating that new development should not be considered here. However, it is acknowledged that brownfield redevelopment may be required to ensure the long-term prosperity of the area. Therefore, prior to any development of areas behind defences, the Sequential and Exception Tests must be undertaken in the first instance in accordance with Table D3 of PPS25. Where the need to apply the Exception Test is identified, the results of this Level 2 SFRA must be utilised. Where the relevant tests are passed, development should be set back from the defence and the identified 'significant' and 'extreme' hazard areas avoided. Instead, development should be steered towards the identified low and moderate hazard areas, where flood resistance and resilience measures can sufficiently mitigate the risk (see points for development in Flood Zone 3a). Dry pedestrian access / egress must be ensured for the 1 in 100 year plus climate change event and an evacuation plan should be prepared. For major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer. This study has shown that the defences overtop in a 1 in 100 year plus climate change event, therefore this may occur during the lifetime of the development. The River Severn CFMP policy unit for this area is to 'take further actions to sustain the current level of risk into the future (responding to the potential increase in risk from urban development, land-use change and climate change). However, developer contributions may still be sought to increase the level of the defences to mitigate the effects of climate change on flood risk in the area. Finally, the cumulative impact of loss of storage at the allocation site on flood risk elsewhere within the flood cell must be assessed, and suitable methods employed to ensure no loss of storage (this may have to be facilitated by vacant ground floors).

At Coleham, two sites are located behind the defences (Sites **SH3** and **SH38**). Flood Zone data gathered from the Environment Agency as part of the Shropshire Level 1 SFRA, indicates that site **SH3** lies fully in Flood Zone 3b and site **SH38** lies partially in Flood Zone 3b. Modelling undertaken as part of this commission indicates that both of these sites are not located in Flood Zone 3b, because the Coleham defences have been included in the model. The site is therefore in an area benefitting from a flood defence. Although both of the sites benefit from the Coleham defences, the flood risk increases substantially as a result of climate change with the modelling indicating the defences overtop and the flood hazard increases from moderate to predominantly extreme (danger for all). As such, alternative sites in lower flood risk areas (Flood Zone 1) should be considered in preference to these sites. Should the Sequential Test be passed, development may be suitable as indicated in the paragraph above regarding development behind Frankwell defences.

The Level 2 SFRA modelling has indicated that there are extensive areas through Shrewsbury which are affected by flood risk. All brownfield re-development must undergo the Sequential Test and, where applicable, the Exception Test.

Where sites in flood risk areas have passed the Sequential and Exception tests and are allocated for development, the Council should adopt the principle of avoidance by ensuring, where possible, that areas of a site affected by Flood Zones 2, 3a, 3a plus climate change and 3b remain as open space. The avoidance of flood risk is important in the development of sustainable communities and will deliver a positive reduction in flood risk by reducing the impact that flooding may have on the community (by reducing the number of people within the site that would otherwise be at risk) and reducing flood risk elsewhere. It can also help the Council to achieve green space targets.

A policy of managed retreat should also be adopted by the Council, particularly for sites where existing development is located within high hazards areas. For example, site **190** lies predominantly within Flood Zone 1, however, the northern part of the site is located within Flood Zones 2, 3a and 3b. In the first instance, alternative sites in Flood Zone 1 should be considered in preference to this site. Flood Hazard information indicates that for the 1 in 20 and 100 year events, the flood hazard is low to moderate, increasing to extreme during the 1 in 100 year climate change event. Should the site pass the Sequential Test and be allocated for development, a policy of managed retreat should be adopted, returning the northern part of the site to natural floodplain and guiding built development to the area of the site within Flood Zone 1. This principle can be applied to any similar development site, where parts of the site are in identified risk areas. Opportunities to provide flood risk reduction benefits both on-site and elsewhere by developing the site sequentially should always be implemented.

For all new developments, the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff (see below).

Developments should seek to reduce the overall level of flood risk in the area and beyond through the layout and form of the development. There is no significant flood risk constraint on the 'use' proposed for future developments within the Low Probability Flood Zone 1, although the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff. An FRA will be required to demonstrate that runoff from the site is reduced, thereby reducing surface water flood risk. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions. For all sites, the post development runoff volumes and peak flow rates should be attenuated (1 in 100 year + climate change) to the Greenfield (pre-development) condition with a minimum reduction of 20%, and mimic the surface water flows arising from the site prior to the proposed development.

Options for de-culverting should be explored wherever possible. In the event that this is not possible, an assessment of the structural integrity of the culverts should be carried out prior to any development in the vicinity. Any remedial works to ensure the culverts' longevity (commensurate with the lifetime of the development) should be carried out. Developer contributions should be sought for this purpose.

The Council should develop a culvert maintenance schedule, to periodically clear culverts of debris, which will reduce the risk of blockage during flood events.

6.5 Development Control Policies

For the purposes of development control, detailed policies will need to be set out to ensure that flood risk is taken account for both allocated and non-allocated 'windfall' sites. The following policy objectives are recommended for all sites in Shrewsbury:

- **Application of the Sequential Test** - Use the Sequential Test to locate all new development (site allocations) in least risky areas, giving highest priority to Flood Zone 1. Where the Sequential Test alone cannot deliver acceptable sites, the Exception Test will need to be applied.

- **Protect the functional floodplain (in Greenfield and previously developed areas) –** Avoid development in the Greenfield functional floodplain in the first instance. Identify opportunities for making space for water on previously developed areas by reinstating the functional floodplain.

- **Site Layout** - apply the sequential approach within the development site by locating the most vulnerable elements of a development in the lowest flood risk areas in the first instance. The use of flood risk areas (i.e. Flood Zones 2, 3a and 3b) for recreation, amenity and environmental purposes can provide an effective means of flood risk management as well as providing connected green spaces with consequent social and environmental benefits.

- **Enhance and restore the river corridor** - identify opportunities to undertake river restoration and enhancement as part of a development to make space for water.

- **De-culvert wherever possible.** Where this is not possible, an assessment of the structural integrity of the culvert, with any required remedial work, should be carried out prior to the development. A maintenance schedule should be developed for all culverts to ensure regular clearance. Construction of new culverts should be avoided wherever possible. Investigations should be undertaken to negate the need for further culverting.

- **Set development back from watercourses -** any riverside developments should leave a minimum 8 metre wide as undeveloped buffer strip, maintaining the river and its floodplain as an enhancement feature and allowing for routine maintenance.

- **Reduce surface water runoff from new developments –** any development must ensure that post development runoff volumes and peak flow rates are attenuated to the Greenfield (pre-development) condition with a minimum reduction of 20%. SUDS should also be a requirement for all new development and space should be specifically set-aside for SUDS and used to inform the overall site layout

- **Maintenance of existing flood storage areas, including informal** – existing storage areas should be maintained and safeguarded from development.

- **Ensure a development is 'Safe' -** For residential developments to be classed as 'safe', dry pedestrian access should be provided to and from the development without crossing through the 1 in 100 year plus climate change floodplain. Major or vulnerable development should not be permitted in Flood Zones 2 and 3 unless it can be satisfied that evacuation can be carried out up to the 1 in 1000 year event.

In addition, the following guidance should be followed:

6.6 *Requirements for Flood Risk Assessments and Guidance for Dealing with Windfall Sites*

The following reflects the minimum requirements under PPS25 for a Flood Risk Assessment (reference should be made to Tables D.1-D.3 in PPS25). Appendices A and B also outline FRA requirements for specific development sites, which should also be considered. This guidance could also be used to help the Council to deal with non-allocated 'windfall' sites.

6.6.1 *Sites in Flood Zone 1*

Four of the development sites through Shrewsbury (Sites **160, SH52**, **SH55** and **SH76A**) fall entirely within Flood Zone 1, with no known local flood risk issues. In many cases sites fall in Flood Zone 1 but have a small drain flowing through it, with no associated Flood Zone information. This section details the requirements for development in Flood Zone 1. Some sites may have specific recommendations, in addition to those put forward here, which are detailed in Appendices A and B.

- In accordance with Table D3 of PPS25, any type of development can be located in Low Probability Flood Zone 1.

- The vulnerability of the development from other sources of flooding should be considered as well as the effect of the new development on surface water runoff.

- The potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water runoff, with appropriate mitigating action, should be incorporated in a Flood Risk Assessment (FRA) for the site. This should take the form of a Drainage Impact Assessment (DIA), required to demonstrate that runoff from the site is the same as in the predevelopment case, thereby ensuring flood risk is not increased (in all cases, betterment should be achieved). This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions. Where possible these should be strategic SUDS. Strategic SUDs are systems that serve multiple development plots and will primarily take the form of swales (grassed wet or dry ditches) and ponds mimicking the natural environment as closely as possible where constraints allow, effectively creating an artificial watercourse. Space should also be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Telford and Wrekin Sustainable Drainage Systems Review document, Halcrow (2008) for further details on appropriate SUDS techniques for the Telford and Wrekin area.

- Where a small watercourse or drain, with no Flood Zone information, either runs through the site or follows the boundary of the site, a development easement from the top of bank should be applied. The exact distance of the easement should be discussed with the Environment Agency, but should typically be 8m, to allow appropriate access for routine maintenance and emergency clearance.

6.6.2 *Sites in Flood Zone 2*

Where sites are substantially affected by Flood Zone 2, alternative sites in Flood Zone 1 should be considered in preference as part of the Sequential Test process. Specific recommendations for each affected site are given in Appendices A and B.

- In accordance with Table D3 of PPS25, land use within Medium Probability Flood Zone 2 should be restricted to the 'essential infrastructure', 'water compatible', 'less vulnerable' and 'more vulnerable' categories. Only if the Sequential Test process has been carried out and passed should such development occur in Flood Zone 2.

- 'Highly vulnerable' uses in Flood Zone 2 will have to pass the Exception Test.

- An FRA will be required, which should confirm flood extents and levels.

- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 600mm.

- For new development sites incorporating vulnerable development, dry pedestrian access to and from the development should be possible above the 1 in 100 year plus climate change flood level.

- For existing Brownfield Sites and sites containing other less vulnerable uses, the provision of dry pedestrian access to the site should be considered where possible with each site being considered individually according to the consequences of flooding (including the flood depth, velocity, hazard and distance). The Environment Agency promotes the following hierarchical approach in decreasing order of preference:

- Safe dry pedestrian and vehicle access at the 1 in 100 year plus climate change event

- Safe dry access for pedestrians at the 1 in 100 year plus climate change event

- Where a dry route is not possible, a pedestrian flow route with low flood hazard (depth and velocity) with no risk to people, including consultation with Emergency Services/Planners and consideration of Flood Evacuation Plan

- Where a flood free route for vehicles are not possible, a route for vehicles where flood hazard (depth and velocity) is low to permit access for Emergency vehicles, including consultation with Emergency Serivces/Planners and consideration of Flood Evacuation Management Plan.

- The development should be safe, meaning that: people (including those with restricted mobility) should be able to remain safe inside the new development up to a 1 in 1000 year event; and rescue and evacuation of people from a development (including those with restricted mobility) to a place of safety is practicable up to a 1 in 1000 year event, for vulnerable development.

- The development should incorporate flood resistance and resilience measures.

- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.

- SUDS should be implemented to ensure that runoff from the site (post development) is reduced. Space should be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Telford and Wrekin Sustainable Drainage Systems Review document, Halcrow (2008) for further details on appropriate SUDS techniques for the Telford and Wrekin area.

- Residents should be made aware that they live in a flood risk area, and should be encouraged to sign up to Floodline Warnings Direct, should a Flood Warning system exist (as indicated by the Level 1 SFRA).

6.6.3 *Sites in Flood Zone 3a*

A number of development sites are substantially affected by Flood Zone 3a, in which case it has been recommended that alternative sites in lower risk areas are considered. For the modelled extents through Shrewsbury, Flood Zone 3b has been produced. However, for other watercourses within the Borough, Flood Zone 3b has not been modelled. Therefore when carrying out the Sequential Test in these areas, the Council should assume that where Flood Zone 3b has not been modelled, its extent would be equal to Flood Zone 3a, unless, or until, an FRA can demonstrate otherwise.

Wherever possible, development in Flood Zone 3a should be avoided, due to the reduction in flood storage that can result and the increased flood risk which can occur as a result of climate change. However, for the sake of completion and for future reference, the following recommendations are put forward for development of Flood Zone 3a:

- Land use with High Probability Flood Zone 3a should be restricted to the 'less vulnerable' and 'water compatible' uses to satisfy the requirements of the Sequential Test.
- 'More vulnerable' uses in Flood Zone 3a will have to pass the Exception Test.
- An FRA should be prepared for the site, which should confirm flood extents and levels.
- Properties situated within close proximity to formal defences or water retaining structures (reservoirs/canals) will require a detailed breach and overtopping assessment to ensure that the potential risk to life can be safely managed throughout the lifetime of the development. The breach analysis carried out in this Level 2 SFRA should be used where applicable. The nature of any other breach failure analysis should be agreed with the Environment Agency. For breaches of canals, British Waterways should be consulted.
- The development should not increase flood risk elsewhere, and opportunities should be taken to decrease overall flood risk.
- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 600mm.
- For new development sites incorporating vulnerable development, dry pedestrian access to and from the development should be possible above the 1 in 100 year plus climate change flood level.

- For existing Brownfield Sites and sites containing other less vulnerable uses, the provision of dry pedestrian access to the site should be considered where possible with each site being considered individually according to the consequences of flooding (including the flood depth, velocity, hazard and distance). The Environment Agency promotes the following hierarchical approach in decreasing order of preference:

    - Safe dry pedestrian and vehicle access at the 1 in 100 year plus climate change event

    - Safe dry access for pedestrians at the 1 in 100 year plus climate change event

    - Where a dry route is not possible, a pedestrian flow route with low flood hazard (depth and velocity) with no risk to people, including consultation with Emergency Services/Planners and consideration of Flood Evacuation Plan

    - Where a flood free route for vehicles are not possible, a route for vehicles where flood hazard (depth and velocity) is low to permit access for Emergency vehicles, including consultation with Emergency Serivces/Planners and consideration of Flood Evacuation Management Plan.

- The development should be safe, meaning that: people (including those with restricted mobility) should be able to remain safe inside the new development up to a 1 in 1000 year event; and rescue and evacuation of people from a development (including those with restricted mobility) to a place of safety is practicable up to a 1 in 1000 year event, for vulnerable development.

- The development should incorporate flood resistance and resilience measures.

- Basements should not be used for habitable purposes. Where basements are permitted for commercial use, it is necessary to ensure that the basement access points are situated 600 mm above the 1 in 100 year flood level plus climate change.

- An evacuation plan should be prepared in consultation with the Council's Emergency Planning team.

- Residents should be made aware that they live in a flood risk area, and should be encouraged to sign up to Floodline Warnings Direct, should a Flood Warning system exist (as indicated by the Level 1 SFRA).

- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.

- SUDS should be implemented to ensure that runoff from the site (post development) is reduced. Space should be set-aside for SUDS at the master planning stage.

6.6.4 *Sites in Flood Zone 3b*

Modelled flood outlines have been produced for Flood Zone 3b. This section should be used to understand the requirements of development.

- Development in High Probability Flood Zone 3b should be restricted to 'water-compatible uses' only.

- PPS25 dictates that 'essential infrastructure' can be located in Flood Zone 3b if the Exception test is passed. However, appropriate judgement should be exercised when attempting the Exception Test for essential infrastructure in Flood Zone 3b. Essential infrastructure includes: essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk; and strategic utility infrastructure, including electricity generating power stations and grid and primary substations. Essential transport infrastructure may be appropriate if designed in such a way that flood flow routes and flood storage areas are not affected (e.g. designing a bridge to cross the flood risk area). However, utility infrastructure may be less appropriate due to the potential consequences that may occur should the utility site become flooded (as demonstrated by the flooding of Mythe Treatment Works and near-flooding of the power station in Gloucestershire during the summer 2007 flood events).

- 'Essential infrastructure' in this zone must be designed and constructed to remain operational in times of flood and not impede water flow.

Appendix A

Assessment of potential allocations

Appendix B

Assessment of potential allocations in the modelled study area

Appendix C

Sequential & Exception Test Process

Appendix D

Maps of Modelled Outputs

Appendix E

Environment Agency Sign-off Letter