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Bedford Borough Strategic Flood Risk Assessment

Level 2

Final Issue

Plan Design Enable

Bedford Borough Strategic Flood Risk Assessment

Level 2

Final Issue

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Contents

Section Page

List of Tables

List of Figures

Appendices

Glossary of Terms

Term	Meaning / Definition
AAD	Average Annual Damages
AEP	Annual Exceedance Probability
AFFMS	Anglian Flow Forecasting Modelling System
CFMP	Catchment Flood Management Plan
CSRIP	Core Strategy & Rural Issues Plan
Defra	Department for Environment, Food and Rural Affairs
DG5	Water Companies Record of Sewer Flooding
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FSR	Flood Studies Report
FWD	Floodline Warnings Direct
GIS	Geographical Information System
LDDs	Local Development Documents
LDF	Local Development Framework
LPA	Local Planning Authority
Main River	This term is used for watercourses shown on statutory maps held by the Environment Agency and Defra. They can include any structure or appliance for controlling or regulating the flow of water into, in or out of the channel. The Environment Agency has permissive powers to carry out works of maintenance and improvement on these watercourses (Main Rivers).
MKSMSRS	Milton Keynes and South Midlands Sub-Regional Strategy
NFCDD	National Flood and Coastal Defence Database
NFFS	National Flood Forecasting System
PAR	Project Appraisal Report
PPS1	Planning Policy Statement 1: Delivering Sustainable Development
PPS25	Planning Policy Statement 25: Development and Flood Risk
PPS3	Planning Policy Statement 3: Housing
RFRA	Regional Flood Risk Assessment
RPB	Regional Planning Boards
RSS	Regional Spatial Strategy
SFRA	Strategic Flood Risk Assessment
SFVI	Social Flood Vulnerability Index
SMD	Soil Moisture Deficit
SWMP	Surface Water Management Plan

SOP	Standard of Protection
SuDs	Sustainable Drainage Systems
TCAAP	Bedford Town Centre Area Action Plan
WCS	Water Cycle Strategy

Annual Exceedance Probability (AEP)

The severity of the events discussed in this document are defined as Annual Exceedance Probabilities (AEP), the table below provides a summary of AEP and corresponding Return Periods.

The AEP is the probability that there will be an event exceeding a particular severity in any one year. The Return Period is the average duration (in years) between events of a particular severity.

Annual Exceedance Probability	Return Period
50%	1 in 2yrs
10%	1 in 10yrs
4%	1 in 25yrs
3.3%	1 in 30yrs
2%	1 in 50yrs
1.33%	1 in 75yrs
1%	1 in 100yrs
0.5%	1 in 200yrs
0.4%	1 in 250yrs
0.1%	1 in 1000yrs

Non Technical Summary

Bedford Borough Council has commissioned Atkins to carry out a Strategic Flood Risk Assessment (SFRA) for the Bedford Borough area. This SFRA has been developed in accordance with the Planning Policy Statement Note 25 (PPS25) and in consultation with key stakeholders including, Bedford Borough Council, the Environment Agency, the Bedford Group of Internal Drainage Boards (IDBs) and Anglian Water.

All of the data utilised for this SFRA, is the best available data up until October 2009. Any site specific Flood Risk Assessments (FRA) carried out following October 2009 should also ensure that the best available data is utilised. No additional hydraulic modelling has been carried out for this Level 2 SFRA with the exception of re-running available models.

This Level 2 SFRA builds upon the information and addresses the recommendations provided within the Level 1 SFRA. The Level 1 SFRA completed in July 2008 was sufficiently detailed to allow the application of the Sequential Test as outlined in PPS25. In addition the information in the Level 1 SFRA is adequate to identify whether development is located within suitable areas based on flood risk and whether the Exception Test would be required. This Level 2 SFRA provides further detail on flood risk, including the nature of the flood hazard, to the Bedford Borough, with particular attention to areas where there is development pressure, such that it can facilitate the application of the Sequential and Exception Tests.

The main source of flooding within the Bedford Borough is from the River Great Ouse, and as such is fluvial in its nature. In developed areas, the impacts of climate change are minimal, further work (currently being developed and not available for this study) is being carried out to refine climate change outlines for Elstow and Wilstead. At present these areas are covered via the Environment Agency Flood Zones, specifically the Flood Zone 2 (Medium probability of flooding) outline.

This SFRA has highlighted that the majority of areas that have been allocated for development within Bedford Boroughs Local Plan are situated within Flood Zone 1 (Low probability of flooding), which according to the sequential test in PPS25 would result in no restrictions upon the development type. There are some allocated development areas that are located within Flood Zone 2 (Medium probability of flooding) and Flood Zone 3a (High probability of flooding) and Flood Zone 3b (the Functional Floodplain). These sites will have restrictions on the type of development that can be carried out as per PPS25. A majority of these areas have already had further site specific FRAs developed for them.

Defra has recently undertaken a national study to identify areas that are at risk from surface water flooding. In this Defra study, the key service centre of Great Barford has been identified as having 470 properties at risk. It is recommended that the Marston Vale Surface Waters Plan should be updated to reflect current Surface Water Management Plan (SWMP) guidance, incorporating the Key Service Centres that are highlighted as being at risk from surface water in more detail. The update will also provide a strategic approach to surface water management in the Bedford Borough.

Due to data limitations it was not possible to look in detail at the assessment of flood hazard to each of the Key Service Centres. Hazard assessments that have taken place make use of currently available hydraulic model data. It is recommended that hazard assessments should be undertaken on a site specific FRA basis.

The original scope of this Level 2 SFRA was to identify the Functional Floodplain and the climate change scenario for Flood Zone 3 for the Key Service Centres, however in some cases this was not possible due to a lack of available hydraulic models. In the development of this Level 2 SFRA, a series of assumptions have been developed for areas where no existing hydraulic models exist. These assumptions were developed in conjunction with Bedford Borough Council, the Environment Agency and the Bedford Group of Internal Drainage Boards and are listed below:

- All areas at risk of flooding are undefended;
- The Functional Floodplain has been classed as any area lying within Flood Zone 3 (high probability); and

- The climate change outline is taken to be the same as the current Flood Zone 2 (medium probability) outline.

The Bedford Borough SFRA should be viewed as a living document and updated periodically to include new and further data that relates to flood risk within the Bedford Borough.

The outcome of this Level 2 SFRA has allowed a series of recommendations to be developed, which will enable further future development to be appropriately allocated in terms of flood risk.

1. Introduction

1.1 The Need for a Strategic Flood Risk Assessment

Planning Policy Statement 25: Development and Flood Risk (PPS25) (Ref: 1) was published in December 2006 as the overarching policy document that incorporates flood risk into the planning process. The aim of PPS25 is to ensure new development is not located where it is at an unacceptable risk of flooding, nor does it contribute to an increase in flood risk elsewhere within the catchment. PPS25 outlines that Local Planning Authorities (LPA) should undertake a Strategic Flood Risk Assessment (SFRA) as part of the evidence base for the Local Development Framework (LDF) to ensure strategic land use planning. This facilitates catchment wide development by providing information to allow the Sequential Test to be performed which ensures development is proposed in sustainable locations.

An SFRA is completed in two stages; the Level 1 assessment forms the baseline for flood risk assessment within the catchment with reference to proposed development and the Level 2 assessment will provide a more detailed report of flooding issues and mitigation measures. The Level 1 Bedford Borough SFRA was completed by Atkins in July 2008 and has informed this Level 2 assessment. The results from this Level 2 report incorporate the findings from the Level 1 assessment and as such cross reference between the two SFRA documents is not necessary.

The SFRA will inform smaller scale Flood Risk Assessments (FRAs) that must be completed for development proposals located in Flood Zones 2 or 3 (see section 2.1.4 for explanation), or those that have the potential to increase flood risk elsewhere. These small FRAs are site specific and have to be submitted along with the planning application for the new development to ensure flood risk has been taken into account at the site specific planning stage of the development.

1.2 Level 1 Strategic Flood Risk Assessment

The Level 1 assessment provided an overview of flood risk in relation to development within the Bedford Borough in context with national, regional and local policy and with reference to the new Bedford Development Framework.

The Level 1 SFRA outlined a number of conclusions that were used for the completion of this Level 2 document, these conclusions are summarised below:

- The primary source of flooding in the Bedford Borough would be fluvial from either the River Great Ouse which flows through the study area or from any of the number of smaller main rivers or from the Bedford Group of Internal Drainage Boards (IDB) maintained watercourses;
- Parts of the Bedford Borough are at risk from surface or foul sewer water flooding;
- The risk from groundwater flooding is low, however re-development or altering the old mineral workings within the Bedford Borough may give rise to changes in groundwater flow;
- The only formal flood defences within the Bedford Borough are located within the town centre. The Environment Agency own and maintain the majority of these defences and the IDB are responsible for maintaining defences along their watercourses. However there are also a number of flood storage areas within Marston Vale, Great Barford and Harrold, of which the IDB are responsible for the first two and Bedford Borough for the later;
- The Environment Agency currently operate a flood warning system for which 25-30% of properties receive flood warnings in Bedford Borough;

- Flood risk is predicted to increase for some properties within the Bedford Borough due to climate change; and
- There is potential to include Sustainable Drainage Systems (SuDs) within future developments within the Bedford Borough. Bedford Borough Council wishes to adopt a strategic approach to managing surface water within the Bedford Borough.

The Level 1 assessment also outlined 11 recommendations for the Level 2 SFRA these are summarised below:

1. The Level 2 SFRA should build on the Level 1 SFRA by providing advice on flood defence and mitigation for the Key Service Centres and Growth Areas within Bedford Borough;
2. Refine the extent of flood risk to determine Flood Zones 3a and 3b and the climate change flood outline;
3. Undertake detailed assessment of the flood risks within the Key Service Centres in consultation with Bedford Borough Council;
4. Assess the details of the proposed Milton Keynes to Bedford canal in terms of flood risk;
5. Analyse potential groundwater flooding for the villages of Keysoe, Wilstead, Cotton End and Cardington.
6. Assess changes in groundwater flow as a result of land use change as this may potentially cause groundwater flooding;
7. Recommend development control policies for both discharging surface water and flood risk for different catchments, land uses and locations;
8. Identify potential opportunities for restoring the natural floodplain, including the relocation of development in floodplains to sites of lower risk;
9. Identify options to raise flood defences that have a protection level of lower than 1% AEP to the required standard;
10. Develop guidance for developers to provide a tool for Bedford Borough Council for use with the planning approval process, which includes a checklist of technical analysis for flood risk; and
11. Prepare a Flood Risk Factsheet for each Key Service Centre as a quick reference for planners, engineers and interested members of the public.

1.3 Scope of This Document

This Level 2 SFRA covers the Bedford Borough area, with the exception of the town centre. A separate SFRA, Bedford Town Centre Area Action Plan (TCAAP) (Ref: 2) has been undertaken for this area by WSP consultants on behalf of Bedford Borough Council in 2006 and should be read in conjunction with this document.

The aim of this document is to provide additional information to the Level 1 SFRA by providing details on flooding and flood defence/mitigation in reference to future development.

Many of the recommendations in section 1.2 have been carried out for the completion of the Level 2 assessment. One omission is recommendation 4. It was deemed inappropriate by Bedford Borough Council and the Environment Agency to define the change in flood risk resulting from the proposed Milton Keynes to Bedford canal because detailed plans have not yet been made available. When the canal plans are finalised a site specific FRA will need to be completed in accordance with PPS 25.

This document outlines the suitability of the development allocations identified in the Council's Core Strategy and Rural Issues Plan (Ref: 3) in terms of flood risk. This involved using hydraulic modelling for Growth Areas and Key Service Centres to ensure the potential risks at possible

development sites are properly assessed. Modelled flood outlines produced from various existing models have been utilised for this study. Further details are included within section 3.3.2.

To aid with future development proposals, a developer flood risk fact sheet has been produced for the potential growth areas aimed at planners, engineers, developers and members of the public who require a quick reference guide to flood risk within these Key Service Centres. The Factsheets concentrate on fluvial flooding because the Water Cycle Strategy (WCS) completed by Halcrow on behalf of Bedford Borough and Mid Bedfordshire District Councils (Ref: 4) contains a fact sheet for surface water flooding and SuDs. It is advised that the Bedford WCS (Ref: 4) is read in conjunction with this Level 2 SFRA document. Figure 1.1 is taken from the Surface Water Management Technical Defra guidance (Ref: 5) illustrates how a SFRA ties in with a WCS and other documents.

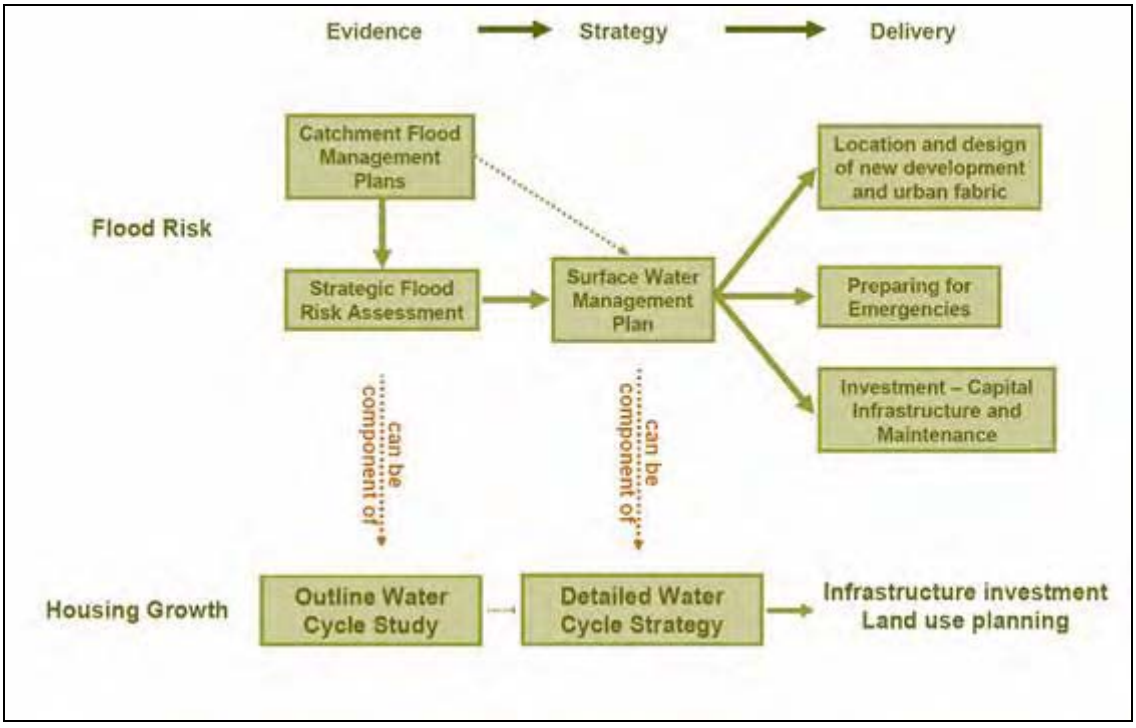

Figure 1.1 – Figure taken from the Surface Water Management Technical Guidance (Ref: 5) demonstrating the linkage between SFRAs and WCSs.

The purpose of an SFRA is to provide necessary information for the Sequential Test to be carried within the respective region. The Sequential Test is carried out to determine that there are no reasonably available sites in areas with a lower probability of flooding that would be appropriate to the type of development or land use proposed.

In addition this Level 2 SFRA provides information for the completion of Part C of the Exception Test. PPS25 states that for Part C of the Exception Test to be passed a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

The following objectives have been proposed for this Level 2 SFRA:

- Provision of a robust Bedford Borough Level 2 SFRA that follows best practice and national guidance;
- An outline of recommendations for site specific FRAs;
- Building upon the Level 1 SFRA and data and information held by the Environment Agency on Flood Risk Zones and flood management strategies including Catchment Flood Management Plans (CFMPs) and Project Appraisal Reports (PARs);
- Integration with other strategies and research;

- Informing site specific documents such as the Area Action Plan and Supplementary Planning Documents; and
- Providing the evidence base to undertake the Sequential Test when allocating developments

This document is designed such that it does not have to be read in conjunction with the Level 1 SFRA; all the information contained in the Level 1 report is used for the Level 2 study and incorporated into this document where updated information is not available.

It is important that this document is read in conjunction with other reports that are relevant to flood risk within the Bedford Borough such as the Bedford TCAAP (Ref: 2) and the Bedford WCS (Ref: 4), as well as national, regional and local planning documents.

2. Planning Policy Relating to Flood Risk

The planning process is driven by policy at national, regional and local levels and flood risk is a major component of this. The overarching policy for flood risk is Planning Policy Statement 25: Development and Flood Risk (PPS25) (Ref: 1). Regional and local policy in the form of development plans and other similar documents support this national guidance. This section outlines the various policies on development that relate to flood risk.

2.1 National Planning Policy

Planning Policy Statements set out the Governments policies on various aspects of land use planning in England. These national policies play a fundamental role in shaping Regional Spatial Strategies (RSS) and Local Development Frameworks (LDFs) which are produced by Regional Planning Bodies (RPBs) and Local Planning Authorities (LPAs). PPS25 sets out the requirements for a SFRA, however PPS1 and PPS3 have also been used for the preparation of this document.

2.1.1 Planning Policy Statement 1: Delivering Sustainable Development

The Governments objectives for sustainable development are set out in PPS1 (Ref: 6). This means that the sustainability of the development must be considered over the life of the development, with reference to changes in the physical environment and climate.

An example of changes in the physical environment is the change in natural hazards, including flooding, that may pose a risk to the development. The consequence of this is that LPAs must recognise the potential hazards to allocated development sites in order to site development in areas that are at a limited risk. However in certain circumstances development would be proposed on sites that are potentially at risk from natural hazards when the development satisfies other sustainability issues. PPS1 supports such development if it can accommodate the natural hazard and associated potential changes so that the development is safe, sustainable, durable and adaptable without causing an increased risk elsewhere.

2.1.2 Planning Policy Statement 3: Housing

The Governments housing objectives are set out in PPS3 (Ref: 7) and as such should be used when LPAs and RPBs prepare their Local Development Documents (LDDs) and RSSs. Whilst identifying broad locations for potential development sites, LPAs must take into account the physical constraints that might be imposed at each location to comply with PPS3.

PPS3 sets the annual target that 60% of new housing development is constructed on brownfield sites in order to make effective use of land and as such LPAs should strive to allocate land on previously developed areas. However PPS3 recognises that this is not always possible as sites that have been previously developed are not always suitable for housing development. This can include when a previously developed site that has the potential for redevelopment is located within a flood risk area and as such is not suitable for housing development.

2.1.3 Planning Policy Statement 25: Development and Flood Risk

Planning Policy Guidance Note 25 (PPG25) was produced in 2001 to set out the Governments policies on development relating to flood risk. This has now been superseded following the publication of Planning Policy Statement 25 (PPS25) (Ref: 1) in December 2006. Accompanying PPS25 is a Practice Guide which details guidance on the production of SFRAs (Ref: 8). PPS25 is the overarching document for development and flood risk and requires local authorities to produce an SFRA.

There several notable differences can be summarised between PPG25 and PPS25 as PPS25 promotes:

- A more strategic planning approach to managing flood risk;

- Stronger guidance on flood risk assessments at all stages in the planning process;
- A clarified Sequential Test;
- An Exception Test to be implemented when development is proposed in areas at risk of flooding, but where not developing these sites will cause social or economic problems; and
- Clearer guidance on how to assess the impacts of climate change.

The aim of PPS25 is to ensure that new development is not at an unacceptable risk of flooding by steering development to areas of lowest risk. Where development is unavoidable in areas at risk from flooding PPS25 ensures that the development is safe and without increasing flood risk elsewhere and where possible reducing overall flood risk.

The completion of RSSs, Development Plan Documents and Supplementary Planning Documents must involve the undertaking of a Sustainability Appraisal as required by the Planning and Compulsory Purchase Act 2004. To contribute to the Sustainability Appraisal freestanding flood risk assessments must be completed; RPBs should prepare Regional Flood Risk Assessments (RFRAs) and LPAs should prepare SFRAs. Aspects of the SFRA will help inform the more detailed site specific FRAs. This will aid RPBs and LPAs in conforming to PPS25 by preparing and implementing planning strategies that promote sustainable development. The Environment Agency and other relevant bodies should be consulted when RPBs and LPAs develop their policies and strategies to appraise, manage and reduce flood risk.

PPS25 should be read in conjunction with other national and european policies for flood risk and water management such as Making Space for Water (Ref: 9) and the Water Framework Directive (Ref: 10).

2.1.4 Flood Zone Definition

Environment Agency Flood Map

The Environment Agency's Flood Map was first published on the internet in October 2004. The flood maps show the best estimate of flood extents for the undefended 1% AEP and 0.1% AEP fluvial floodplain and 0.5% AEP and 0.1% AEP tidal floodplain.

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

The Flood Map presents flood risk in accordance with the PPS25 Flood Zones 1, 2 and 3. Appendix A.3 displays an overview of Flood Zones 2 and 3 within the Bedford Borough and Appendix A.10 shows this same mapping, but at a larger scale so that extents of Flood Zones are more clearly defined.

The Environment Agency Flood Zones 2 and 3 show flood risk which does not take into account the presence of flood defences However maps which indicate areas benefitting from defence have been published by the Environment Agency.

PPS 25 Flood Zones

PPS25 splits the Environment Agency's Flood Map into three separate Flood Zones. These Flood Zones should be used when determining the appropriateness of proposed development uses when considering flood risk through the application of the Sequential Test. They represent flooding without flood defences in place.

The Bedford Borough is not at risk from tidal flooding due to its inland location, thus tidal flooding is not discussed further.

Flood Zone 1 is defined as having a 'Low Probability' of flooding and incorporates areas where the annual probability of flooding is lower than 0.1%. PPS25 imposes no constraints upon the type of development within Flood Zone 1.

Flood Zone 2 is defined as 'Medium Probability' with an annual probability of flooding between 0.1 and 1.0% for fluvial flooding. PPS25 recommends that Flood Zone 2 is suitable for most types of development with the exception of 'Highly Vulnerable' (see Table 2.1) land uses as defined in table D2 of PPS25.

Flood Zone 3 is defined as 'High Probability' with an annual probability of flooding of 1.0% or greater for fluvial flooding. PPS25 recommends that appropriate development is based upon a further classification of Flood Zone 3 into 3a High Probability and 3b Functional Floodplain (where water has to flow or be stored in times of flood).

Table D2: Flood Risk Vulnerability Classification, within Annex D of PPS25 outlines the vulnerability classification for different types of development and is included within this SFRA document as Table 2.1 below.

Land Use Vulnerability	Type of Development
Essential Infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood • Wind turbines
Highly Vulnerable	• Police Stations, Ambulance Stations, and Fire stations, Command Centres and telecommunications installations required to be operational during flooding • Emergency dispersal points • Basement dwellings • Caravans, mobile homes and park homes intended for permanent residential use • Installations requiring hazardous substances consent
More Vulnerable	• Hospitals • Residential Institutions such as care homes, children's homes, social services homes, prisons and hostels • Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels • Non-residential uses for health services, nurseries and educational establishments • Landfill and sites used for waste management facilities for hazardous waste • Sites used for holiday or short let caravans and camping, subject to specific warning and evacuation plans.

Land Use Vulnerability	Type of Development
Less Vulnerable	• Police, ambulance and fire stations which are not required to be operational during flooding • Buildings used for: shops, financial, professional, and other services; restaurants and cafes, hot food takeaways; offices; general industry; storage and distribution; non-residential institutions not included in 'more vulnerable'; and assembly and leisure • Land and buildings used for agriculture and forestry • Waste treatment (except for landfill and hazardous waste facilities) • Minerals working and processing (except for sand and gravel working) • Water treatment plants which do not need to remain operational during times of flood • Sewage treatment plants (if adequate pollution control measures in place)
Water Compatible Development	• Flood control infrastructure • Water transmission infrastructure and pumping stations • Sewage transmission infrastructure and pumping stations • Sand and Gravel workings • Docks, Marinas and Wharves • Navigation facilities • MOD defence installations • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location • Water based recreation (excluding sleeping accommodation) • Lifeguard and coastguard operations • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to specific warning and evacuation plans

Table 2.1 – Flood Risk Vulnerability Classification (based on Table D2 of PPS25, Ref: 1)

It is anticipated that there will be an update to Table D2 of PPS25 in December 2009 which includes the clarification of the classification of a number of land uses. The predicted changes to come into affect as of December 2009 are as follows:

- The reclassification of water treatment and sewage works from 'Less Vulnerable' to 'Essential Infrastructure';
- Emergency services (police, ambulance and fire) which are not required in times of flood will be classified at 'Less Vulnerable' although the services required in times of flood will remain under the 'Highly Vulnerable' classification;
- The classification of hazardous bulk waste storage facilities required for energy infrastructure where water is essential will be classified as 'Essential Infrastructure' rather than as 'Highly Vulnerable'; and

- Wind turbines which provide renewable energy will be classified as 'Essential Infrastructure'.

Although these are predicted changes to PPS25, at the time of the SFRA reporting, consultation for these changes is ongoing. Therefore, it is recommended that following December 2009 the updated version of Table D2 in PPS25 should be consulted when determining classification types for new development.

Table 2.2 demonstrates when development, based on the vulnerability classification shown in Table 2.1 is suitable, unsuitable and when the Exception Test is required.

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

✓ Development is appropriate

x Development should not be permitted

Table 2.2 – Appropriate Development for each Flood Zone (based on Table D3 of PPS25, Ref: 1)

Sequential Test

PPS25 states that the Sequential Test should be carried out by LPAs when allocating land in LDDs to demonstrate that there are no sites available for development in areas that are at a lower risk from flooding from all sources.

When an area is at risk from either fluvial or coastal flooding then development should be allocated outside Flood Zones 2 and 3. However if there are no reasonable sites for development within Flood Zone 1 then depending upon flood vulnerability, proposed development sites could be allocated in Flood Zones 2 or 3. The vulnerability classification of development to flood risk is outlined in table D.2 in PPS25 included in this SFRA as Table 2.1.

This SFRA will illustrate areas at risk from flooding and as such should be used to direct land allocations in Flood Zones 2 and 3 to areas at the lowest probability of flooding from all sources. This SFRA assesses land allocations and development control policies in terms of potential sources and probability of flooding with the impact of climate change.

Exception Test

Occasionally it is not possible to locate development in areas that are at the lowest risk of flooding through the Sequential Test. In certain circumstances the Exception Test could be carried out, which, if passed will allow development to go ahead. Table 2.2 in this SFRA is taken from table D.3 in PPS25 and outlines where development is appropriate, not appropriate and when an Exception Test must be carried out depending upon the vulnerability of the proposed development.

The purpose of an Exception Test is to demonstrate that there are wider sustainability reasons for development at a specific location based on issues other than flood risk. In order to pass the Exception Test, which allows development to go ahead, it must be demonstrated that the development satisfies all of the following:

- Provides wider sustainability benefits to the community that outweigh the risk of flooding;
- Is located on land that has been previously developed or there are no other previously developed sites that are suitable for the development; and
- Will be safe without increasing flood risk elsewhere, and where possible, will reduce flood risk overall.

2.2 Regional Planning Policy

2.2.1 East of England Plan

The East of England Plan (Ref: 11) constitutes the RSS for the East of England, which is comprised of Norfolk, Suffolk, Cambridgeshire, Essex, Hertfordshire and Bedfordshire. The RSS aims to contribute towards the achievement of sustainable development through a series of objectives or policies. The document covers the period until 2021, but is considerate of the longer term.

Following the production of the Level 1 SFRA, the final version of the East of England Plan was published in a final format May 2008.

Of the many policies outlined in the document Policy WAT 4 is of primary importance in terms of flood risk and is outlined below in Table 2.3.

Policy WAT 4: Flood Risk Management	Local development documents should:
Coastal and river flooding is a significant risk in parts of the East of England. The priorities are to defend existing properties from flooding and to locate new development where there is little or no risk of flooding.	- Use Strategic Flood Risk Assessments to guide development away from floodplains, other areas at medium or high risk (or likely to be at future risk) from flooding, and areas where development would increase the risk of flooding elsewhere. - Include policies which identify and protect floodplains and land liable to tidal or coastal flooding from development, based on the EA's flood maps, supplemented by historical and modelled flood risk data, catchment flood management plans and emerging policies in shoreline management plans and flood management strategies including managed re-alignment where appropriate. - Only propose departures from the above principals in exceptional cases where suitable land at lower risk of flooding is not available, the benefits of development outweigh the risks from flooding and appropriate mitigation measures are incorporated. - Require that sustainable drainage systems are employed in all appropriate developments - Areas of functional floodplain needed for strategic flood storage in the Thames estuary should be identified and safeguarded by local authorities in their LDDs. - The East of England contains many low-lying areas at risk from flooding, the Fens make up England's largest river floodplain, but areas of river floodplain occur throughout the region. The regions long coastline is also at risk from coastal flooding in places, particularly inland from the Wash. PPS25 refers to the more extensive areas in the region at risk of flooding. - The extensive nature of the regions vulnerability to flooding, combined with existing patterns of development, means that about 140,000 properties are within areas protected by existing flood defences. Where defences are to be maintained, new developments may be acceptable, particularly where

Policy WAT 4: Flood Risk Management	Local development documents should:
	it is making use of previously developed land. However the regions vulnerability to flooding is increasing as a result of climate change and whilst flood defences which protect settlements will be maintained and where appropriate enhanced, a more flexible approach is required in areas outside settlements which are vulnerable to tidal flooding, based on policies of managed re-alignment and relocation. Where some risk is unavoidable it must be considered at all stages of the planning process, to minimise potential damage to property and loss of life whilst avoiding harm to sites of European or international importance for wildlife.

Table 2.3 – East of England Plan: Policy WAT 4 Flood Risk Management

2.3 Local Planning Policy

2.3.1 The Bedford Borough Local Plan and Local Policies

The Bedford Borough Local Plan (Ref: 12) and Core Strategy & Rural Issues Plan (CSRIP) (Ref: 3) outline a series of policies related to the development of the region. Of these policies, those that relate to flood risk and associated issues are detailed in Table 2.4.

Policy	Context	Objectives
Local Plan NE16	Flooding	The Borough Council will not permit development where: • It would intensify the risk of flooding; or • It would be at an unacceptable risk from flooding; or • It would prejudice existing flood defences or interfere with the ability to carry out flood control and maintenance work; or It would adversely affect wildlife habitat in the floodplain unless, the Bedford Borough Council, in consultation with the Environment Agency and Internal Drainage Board as appropriate, is satisfied that the developer will provide appropriate mitigation, protection and compensatory measures.
Local Plan NE24	Protection and Enhancement of Water Resources	The Bedford Borough Council will seek to protect, and where possible, enhance, the water resources in the Bedford Borough by: • Not permitting developments which would adversely affect the quality or quantity of water resources or their amenity or nature conservation value; • Not permitting development which would unduly restrict access to the River and other water bodies with recreational potential; Actively negotiating with developers in order to achieve more sustainable methods of surface water management and drainage.
Local Plan U2	Floodplains	The Bedford Borough Council will not permit development that compromises the capacity of the floodplain, balancing ponds, drainage pipes, channels and other flood defences and works to alleviate flooding, or would be at risk of being flooded, or would unacceptably increase the risk of flooding or pollution through seepage or run off.

Policy	Context	Objectives
CSRIP CP26	Climate Change and Pollution	The council will require development to: • Minimise the emission of pollutants into the wider environment; • Have regard to cumulative impacts of development proposals on air quality, in particular in relation to air quality management areas; • Minimise the consumption and use of energy, including fossil fuels by design and choice of materials; • Unless it can be demonstrated that – having regard to the type of development involved and its design - these requirements are not feasible or viable, achieve a minimum 10% reduction in carbon emissions (below the normal requirement set by the Building Regulations) in all new residential developments and above a threshold of 500m^2 in new non-residential developments by measures which shall include, in new developments above a threshold of 1000m^2 or 50 dwellings, the supply of at least 10% of the energy consumed in the new development to be provided from decentralised and renewable or low-carbon energy sources; • As a minimum, meet the national standards for building performance set by the current Building Regulations. Through the Allocations and Designations DPD process the Council may identify local development or site specific opportunities which justify the adoption and application of higher standards of building performance as set out in the Code for Sustainable Homes. Such higher standards may also be required by the Council where justified by changes in national guidance; • Utilise sustainable construction techniques; • Incorporate facilities to minimise the use of water and waste; • Limit any adverse effects on water quality, reduce water consumption and minimise the risk of flooding; and Developers will be expected to submit a sustainability statement and energy audit with proposals for development.

Table 2.4 – Bedford Borough Local Plan and Local Policies: Policies relating to flood risk

2.3.2 Milton Keynes and South Midlands Sub-Regional Strategy

The Milton Keynes and South Midlands Sub-Regional Strategy (MKSMSRS) (Ref: 13) is a co-ordinated review of the policy for the Milton Keynes and South Midlands sub region, which is an intersection of three RSSs. The MKSMSRS took effect from September 2004 and represents revisions to the three relevant RSS's as detailed below:

1. East Midlands (RSS8)
2. East of England (RPG6 and some of RPG9, that relate to Bedfordshire, Essex and Hertfordshire)
3. South East (RPG9)

One policy within the document relates to flood risk; this policy is set out in Strategic Policy 3: Sustainable Communities and is detailed in Table 2.5.

Strategic Policy 3: Sustainable Communities	Local development documents will:
Sustainable communities will be achieved in the Sub-Region through the implementation of development in accordance with many principles but specific to flood risk is the following principle: managing and reducing demand where appropriate (e.g. demand for water)	-The growth areas will require a strategic approach and investment programme for waste water and surface water drainage management which takes a co-ordinated approach to land drainage, nature conservation, landscape management and open space provision, so that catchment flood risk is not increased and water quality does not deteriorate as a result of the cumulative impacts of development.

Table 2.5 – MKSMSRS: Strategic Policy 3 Sustainable Communities

2.3.3 Marston Vale Surface Waters Plan

The Marston Vale Surface Waters Group was set up in response to the significant amount of new development in the Forest of Marston Vale area (situated to the south west of Bedford).The group comprises of, Bedford Borough Council, the Environment Agency, Forest of Marston Vale, Bedford Group of Drainage Boards and Mid Beds District Council (now part of Central Bedfordshire Council).

As a strategic approach to urban flood risk management the Marston Vale Surface Waters Group instigated the Surface Waters Plan (Ref: 14) which was published in June 2002.

The Surface Waters Plan for Marston Vale relates directly to flood risk and supports local planning policies. The main purposes of the Surface Waters Plan are as follows:

- Promote the policies of the Surface Waters Group;
- Support local plan policies dealing with flooding and surface water drainage;
- Assist with consideration of development proposals;
- Identify solutions for dealing with the impact of development pressure on watercourses and lakes;
- Provide guidance to landowners and developers on approaches to management of surface water; and
- Encourage schemes that result in a range of benefits including management of flood risk and enhancement of the environment.

The purpose of the Surface Water Plan is to encourage landholders, developers and planners to work with the drainage authorities and the Community Forest Team to devise strategic and sustainable solutions for flood risk and surface water drainage in Marston Vale. Additional benefits of increased amenity and conservation value should be incorporated.

In adopting a strategic and integrated approach to flood risk and storm water management the IDB have promoted a number of schemes that provide a model for the successful delivery of sustainable solutions.

In accordance with new government guidance the Marston Vale Surface Water Plan is being revised and updated to fall inline with the new Surface Water Management Plan (SWMP) Guidance (Ref: 5) and the Floods and Water Management Act. It is the responsibility of the Local Authority to coordinate the production of SWMPs. Section 5.4.3 provides further details on SWMPs. For the completion of a Bedford Borough SWMP the Marston Vale Surface Waters Plan could be built upon and updated inline with the Government Guidance (Ref: 5) and current policy and legislation.

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3. Data Collection and Review

3.1 Consultation

All information obtained during the SFRA consultation process has been detailed in Section 3.3 and will feed into the application of the Sequential Test.

3.1.1 Bedford Borough Council

The planning department have been consulted in order to identify areas under pressure from development.

The Bedford Borough Council's drainage team have also been consulted in order to determine if there is any flooding (fluvial or surface water) that the other consultees were not aware of.

There have been no additional data provided for the Level 2 SFRA which was not available for the Level 1 SFRA.

3.1.2 Environment Agency

Bedford Borough Council's area spans only one Environment Agency Region – the Anglian Region, of which the Central Area covers the majority of Bedford Borough. The exceptions are the villages of Hinwick, Podington and Wymington that are covered by the Northern Area. These area offices have been consulted to obtain information on sources of flood risk, hydraulic modelling, flood defences, historic flooding and Flood Warning. Since the completion of the Level 1 alterations and additions have been made to the data sets and as such these have been updated and incorporated into this Level 2 SFRA.

The Environment Agency are also planning to undertake new modelling for all current areas located in Flood Zones within the Bedford Borough in the 2010/2011 financial year. It is estimated that results from this modelling will be available early 2011 and as such after this time it may be necessary to update the flood mapping within this SFRA.

3.1.3 Bedford Group of Internal Drainage Boards

The Bedford Group of IDBs is responsible for the majority of the low lying drains and watercourses that lie within the IDB district within the Bedford Borough.

The IDB for this area have been consulted in order to identify areas at risk of flooding from their watercourses. Information on historic flooding, flood defences and hydraulic modelling from their watercourses has also been obtained. Since the completion of the Level 1 SFRA the IDB have updated their list of anecdotal flooding events and have made this updated data available for inclusion within this Level 2 SFRA. With this exception the data included within the Level 1 SFRA is still the most current information and as such has been utilised for this Level 2 SFRA with permission from the IDB.

3.1.4 Anglian Water

The sewerage infrastructure within the Bedford Borough is maintained by Anglian Water. Anglian Water has supplied information on known surface water flooding locations, historical flooding and information on the assets that they maintain. Since the completion of the Level 1 SFRA amendments have been made to their DG5 register as a number of locations have been removed and a number had been added. This updated version, along with a list of the alterations has been incorporated into this Level 2.

3.1.5 British Waterways

British Waterways have not been consulted as part of the SFRA, as there are no British Waterway owned navigation stretches in the Bedford Borough area.

3.1.6 Other Data Sources

Hydraulic modelling data has also been obtained from a private developer. This data takes the form of GIS mapping layers from hydraulic models and has been used to update the area of Bedford River Valley Park. This modelling carried out by Scott Wilson Group plc was on behalf of Marston Vale Forest Trust.

At present Bedford Groups of IDBs have contracted the consultants Hannah Reed, to complete a modelling and flood mapping project for Elstow Brook. It is envisaged that the output of this data will be used to update the Environment Agency Flood Zone maps. At the time of developing this Level 2 SFRA the flood mapping output for Elstow Brook was still in draft format. Until the Environment Agency have agreed the outlines it is not deemed appropriate to include them within documentation such as this SFRA because they would be subject to change.

Developers undertaking site specific FRAs which are located within borough should aim to use the most up to date mapping e.g. Elstow Brook flood outlines produced by Hannah Reed if available.

3.2 Catchment Characteristics

The Bedford Borough administrative catchment covers 472.2 km^2. There are large portions of rural land within the Bedford Borough and the heaviest urban sector is the town of Bedford. The geology of the Bedford Borough is predominantly comprised of Oxford Clay and Kellaways Beds, with minimal stretches of Cornbrash and Great Oolite.

Soils within the area vary from Efford 1, Evesham 3 and Moreton types. A small portion of the Bedford Borough is not surveyed. Loamy soils are a combination of roughly 40% sand, 40% silt and 20% clay.

Historically Bedford Borough has been subjected to a number of flood events, with the River Great Ouse providing the principal source of flooding. Defence structures have been implemented throughout Bedford town centre to protect the built environment. Flood Warning areas exist along the course of the River Great Ouse as well as in the north of Bedford Borough near Riseley.

3.3 Sources of Flood Risk Information

Information for the Level 1 SFRA has been used for this document and where required has been updated as per the consultation described above. The information given within this Level 2 SFRA is taken from the Level 1 SFRA and where necessary updated, thus cross reference with the Level 1 SFRA is not required.

3.3.1 Historic Flood Events

Analysis of historic flood events is available for the Bedford Borough catchment for a number of watercourses. Information on historical flood events can supplement the understanding of flooding mechanisms and flood extents within a catchment. This section details a number of specific historical flooding events and specific locations where flooding has occurred in the past. Developers should refer to Appendix A10 which provides a historical flood outline to determine if the proposed site has been or is in close proximity to land which has been recorded to have flooded in the past.

Detailed reporting of flood events is available from 1947 up until the present day. The data is both qualitative and quantitative, with the more recent events providing greater detail. Post event reports and flood chronologies indicate that significant flood events which affected Bedford Borough occurred in 1947, 1987, 1992 and 1998.

The following text outlines the flood events in the Bedford Borough catchment taken from records supplied by the Environment Agency and the Bedford Borough Council.

1947

There are contrasting reports detailing the flooding that occurred in 1947.

The first was taken from a report prepared for the Environment Agency in 2000 as part of flood forecasting work (Ref: 15). This report states that extensive road and property flooding occurred throughout Bedford and provides an estimated return period for the flood event in the order of 1% AEP; with a peak of around 290m^3/s, whilst peak water levels in Bedford were around 26.27m AOD.

However a report carried out by the Hydraulic Research Institute in 1966 (Ref: 16), states that the peak flow was 388m^3/s with a 0.4% AEP.

During a review in 2003 of the hydrology in the Bedford Ouse catchment for the April 1998 flood event (Ref: 17 to 20), a review of all historical data was carried out. This review indicated that the flows predicted using the Hydraulic Research Institute model were high in comparison to other studies carried out for the 1998. It can therefore be assumed that the Hydraulics Research Institute model may be over predicting flows in Bedford during the 1947 event.

Should any work be required to calibrate models to the event of 1947, a thorough review of the historic flooding during this event should be undertaken, in order to clarify the discrepancies between the two reports.

1980

In August 1980 Bromham Brook flooded 62 homes and caravans.

1983

On the 1st May 1983 the Bromham Brook overtopped its banks and flooded seven properties; six on Brook Way, one at Wick End. A peak flow was estimated at 24m^3/s based upon water marks, and a peak flow of 18m^3/s was estimated using the Flood Studies Report (FSR) method. The preceding rainfall event was found to have a return period of 10% AEP.

1987

In October 1987 moderately high rainfall fell over the catchment with 20-40mm in 24 hours. This rainfall combined with a Soil Moisture Deficit (SMD) which had reached zero, flooded a number of areas; the road between Kimbolton to Stonely became impassable for 24 hours.

1992

In 1992 the Bedford Ouse catchment was subjected to intense rainfall, between 40-80mm in 24 hours, with SMD values marginally above zero. Flood waters affected the Riseley Brook with 18 properties in Riseley affected. Two industrial developments in Riseley were also flooded.

In Bedford, one property was flooded.

The B660 at Kimbolton had a depth of water of 250mm; on the A45 water depths reached 450mm. A public house in Turvey (a known flood risk area) flooded during this event. Properties were also flooded in Kimbolton, Great Staughton and Bedford. Sharnbrook Road was also inundated by flood waters.

1998

At Easter 1998, the River Great Ouse in Bedford overtopped its banks on Saturday 11th April. Many homes in the north of Bedfordshire and Bedford were flooded and more than 500 homes in Bedford had their electricity supply cut off as electricity supplies went down.

2003

In 2003 the IDB instigated warnings to close the A1 (southbound) at Sandy, however this was in the Mid Bedfordshire district and there was no reports of flooding within the Bedford Borough.

Anecdotal Historical Flood Information from the IDB

In addition to the historical flooding information above the Bedford Group of IDBs have provided known locations of flooding from their records. Since the completion of the Level 1 SFRA the Bedford Group of IDBs has updated its record of flooding events, the updated list was made available for this Level 2 assessment (the additional locations are included as the bottom four bullets in the list below). Further details in relation to these locations such as flood depth, levels and dates have not been made available for this report. The list should be used by developers whose proposed development sites are situated in proximity to any of the areas, as a prompt that further investigation is needed into flood risk at a site specific level. Historic flooding locations include:

- Bedford
  - Lovell Road. The culvert system from Jubilee Park causes road flooding and is assumed to be blocked.
  - Rays Close. Flooding from King's Ditch affects the road and an elderly care home has been evacuated previously.
  - Dame Alice Harpur School. The Environment Agency controls a penstock at this location to isolate flows in Kings Ditch from high flood levels on the main Great Ouse.
- Sharnbrook.
  - The IDB is aware that Mill Road underneath the railway is prone to flooding (closing the road) possibly from blockages in the highway drains or at the outfall with the river.
- Wilden.
  - The road floods due to surface water running from the north.
  - General road flooding has been observed.
  - High Street/East End Lane. Flooding occurs from the watercourse and land to the north.
- Colesden.
  - A pinch point has been noted at the road culvert. Out of bank flooding occurs at this location.
- Wilstead.
  - The IDB is aware that the village lies very wet and is prone to flooding.
- Cotton End.
  - The IDB is aware that the village lies very wet and is prone to flooding.
  - Cotton End Road from Cotton End to Wilstead where a number of flooding incidents have occurred.
- Cople.
  - This village has been identified by the IDB as having flood risk problems.
- Great Barford
  - Road flooding on High Street.
- Wootton
  - Potters Cross where two or three properties were inundated with flood water.
- Harrowden
  - Flooding has occurred off Old Harrowden Road, however at this location only garden flooding occurred.
- Salph End

- Access roads flooded on Brook Lane, however properties were not affected.

The list provided by the Group of IDBs illustrates that four of the key services centres have experienced historical flood events according to their records. This provides an indication that these sites are likely to be vulnerable to flooding as they have experienced it in the past.

Water Level Gauging Locations

There are a number of river gauging stations that have been used to monitor flood levels. At these stations levels are recorded and used for comparison purposes between different flood events. The gauging stations that have been used in this way within the Bedford Borough are:

- Bromham Weir
- Kempston Weir
- Bedford Telytone Duckmill Weir
- Cardington Sluice
- Castle Mill Sluice
- Willington Weir
- Barford Weir
- Roxton Weir

3.3.2 Hydraulic Modelling and Flood Outlines

A number of hydraulic modelling studies have been undertaken within the Bedford Catchment. The majority of these studies have been undertaken on behalf of the Environment Agency and the IDB.

Available models are summarised in Table 3.1 below.

Model Name	Date	Originator	Watercourse
Bedford S105	Feb 2003	EA (Royal Haskoning)	Great Ouse
St Neots S105	Feb 2003	EA (Royal Haskoning)	Great Ouse
Kempston Pre-Feasibility Study	Oct 1999	EA (Royal Haskoning)	Great Ouse
Milton Keynes Drainage Study	Mar 2000	EA (Halcrow)	Great Ouse, Ouzel
Clapham Pre-Feasibility Study	Sep 1999	EA (Royal Haskoning)	Great Ouse
Kimbolton Pre-Feasibility Study	Aug 1999	EA (Royal Haskoning)	River Kym
Olney, Newton Blossomville, Turvey Prefeasibility Study	Aug 2002	EA (Atkins)	Great Ouse
Harrold, Odell, Sharnbrook SOP	Nov 2004	EA (Atkins)	Great Ouse
ARTS2c Bedford Ouse Block	Feb 2006	EA (Atkins)	Inter alia Great Ouse, River Kym, Risely Brook
St Neots Flood Defence	Mar 2008	EA (Atkins)	Great Ouse

Model Name	Date	Originator	Watercourse
Scheme PAR			
Elstow	Ongoing	IDB	Elstow Brook
Bedford River Valley Park	April 2009	Martson Vale Trust (Scott Wilson)	Great Ouse and Elstow Brook

Table 3.1 – Hydraulic Model Summary

The Level 1 SFRA made use of fluvial flood outlines produced from the River Great Ouse reaches that have been modelled on behalf of, or by the Environment Agency including Bedford and St Neots, Clapham and Kempston, Goldington, Harrold, Odell, Sharnbrook, Kimbolton, Olney, Newton Blossomville, Turvey, and St Neots.

The majority of the fluvial flood outlines included in this Level 2 SFRA have been produced using the Bedford Ouse model. The Bedford Ouse model was created by Atkins (2005) (Ref: 17-20), which has recently been updated with longer rainfall periods and tested with flow and level data spanning 2005-2007. This Mike11 model was re-run to produce water level and flow results for the required return periods, and was checked against hydrologically calculated flows at the upstream and downstream boundaries and in the centre of the Bedford Borough reach. The water levels calculated for each return period were mapped to produce the flood outlines.

The flood outlines used within the Level 1 SFRA have been modified by the Environment Agency following subsequent modelling. These altered outlines for Flood Zones 2 and 3 have been made available for this report by the Environment Agency.

This model was used to produce flood outlines resulting from the Bedford Ouse to all the Key Service Centres in the Bedford Borough in addition to Kempston and Bedford (with the exception of the extent of the Bedford TCAAP).

Riseley Brook has also been subject to hydraulic modelling undertaken by the Environment Agency and as such the flood extents produced from this model have been incorporated in to the flood outlines for this Level 2 SFRA. The Key Service Centres within the Bedford Borough are Harrold, Sharnbrook, Clapham, Bromham, Wootton, Stewartby, Wilstead and Great Barford.

Bedford River Valley Park hydraulic model has been developed for a reach of the River Great Ouse and a downstream reach of Elstow Brook by Scott Wilson (Ref: 21). The purpose of the model was to determine areas that would be suitable for wetland habitat creation along the corridor of the River Great Ouse, Elstow Brook and the land within the former gravel pit now owned by Marston Vale Trust. Flow estimations were carried out using the Flood Estimation Handbook (FEH) Statistical Method and a linked two dimensional ISIS-TUFLOW hydraulic model was constructed for the two watercourses. The downstream extent of the model is the weir at Willington Lock. The upstream extent on the River Great Ouse is 170m upstream if the Priory Marina and the upstream extent on Elstow Brook is 500m upstream of the Bedford Road crossing. A range of return periods were modelled up to the 0.1% AEP event, however the only return period also modelled with an allowance for climate change was the 1% AEP event.

The Elstow Brook (the reach upstream of that included within the River Valley Park model) is currently being hydraulically modelled on behalf of the IDB by Hannah Reed but the outputs were not available within the timescales of this SFRA. However it is necessary that developers incorporate mapping, produced from the Elstow Brook modelling study, into FRAs when it becomes available.

A hydraulic model has been developed on behalf of Gallaghers (a private development company) for the development area of The Wixams (Ref. 22). This hydraulic model and associated outlines were not made available to the Bedford Borough for this study, although it appears the Flood Zones 2 and 3 outlines received from the Environment Agency for this Level 2 SFRA have been updated since the Level 1 SFRA in the vicinity of The Wixams development area.

Atkins has recently completed a hydraulic modelling study for Harrold on behalf of the Environment Agency (2009) (Ref: 23). The outlines for this study have been made available for use in this Level 2 SFRA.

The outlines that have been either produced or made available for this SFRA have been merged together to produce outlines for the whole of the Bedford Borough in order to determine all areas at risk from fluvial flooding. These flood maps can be seen in Appendix A.

3.3.3 Anglian Water DG5 Register

The DG5 register which lists known locations of flooding from sewers has been obtained from Anglian Water Services for the Bedford Borough. It has been updated since the completion of the Level 1 Bedford Borough SFRA and a table showing these changes, including the additions and deletions can be seen in Appendix B. It must be noted that the list provided for the Level 1 assessment included street name information. New policy within Anglian Water Services has meant this information cannot be included in this Level 2 assessment due to data protection issues, and as such maps identifying the locations cannot be at a scale which allows individual streets to be identified.

3.3.4 Flood Warning

There are two flood warning areas located within the Bedford Borough. The flood warning area on the River Great Ouse between Sharnbrook and Bedford (Warning Area reference: 052FWFGO3BL) serves the settlements of Blestoe, Radwell, Milton Ernest, Pavenham, Oakley, Clapham, Bromham, Biddenham and Kempston. The flood warning area on the River Great Ouse between Bedford and Offord (Warning Area reference: 052FWFGO4BL) serves the settlements Bedford, Cople, Willington, Gt. Barford, Tempsford, Roxton, Wyboston, Eynesbury, Eaton Ford, St. Neots, Lt. Paxton and Offord.

A forecasting tool has been developed for the Bedford Ouse which is being integrated into the National Flood Forecasting System (NFFS). The NFFS receives real time data from the Regional Telemetry System and the Met Office radar system, which are used to generate forecasts of levels and flows in the regions' rivers. As part of the development of the Bedford Ouse forecasting model a series of reports were produced. The reports produced are as follows:

- Data review – review of hydrometric, topographic and flood history data sets for the Bedford Ouse (Ref: 17);
- Catchment conceptualisation (Ref: 18);
- Model solution – description of the generic modelling solutions that will be used to develop a catchment model of the Bedford Ouse (Ref: 19); and
- Model set-up – description of how the modelling solutions described in previous reports will be applied to Bedford Ouse. The key focus is a schematic of the model as it was built (Ref: 20).

The use of this forecast systems can allow for earlier warning times so that the public and professional partners have a longer period of time to respond to warnings and implement actions to reduce the consequence of flood events.

The Environment Agency sends out warning to the specified flood warning areas with one of four messages:

- Flood Watch – Flooding of low-lying land and roads is expected. Be aware, be prepared, watch out.
- Flood Warning – Flooding of homes and businesses is expected. Act now.
- Severe Flood Warning – Severe flooding is expected. There is extreme danger to life and property. Act now.
- All clear – Flood Watches and Warnings are no longer in force in this area.

Further information on flood warnings can be obtained either by referring to the Environment Agency website or by contacting Floodline on 0845 988 1188.

It should be noted that the Environment Agency will soon be implementing a new system nationally which will alter the way flood warnings are disseminated. This information was not available at the time of issue, therefore it is recommended that the SFRA is updated following these changes.

3.3.5 Bedford Group of Drainage Boards (IDB) Watercourse Surveys

The watercourse surveys undertaken by Bedford Group of IDBs provide cross-section information and can be incorporated into hydraulic modelling. Maps are provided which detail the location of each of the cross-sections along with a photograph at the specific site. Cross-section schematics are available at these points. If detailed site specific FRAs and associated hydraulic modelling are required at locations near watercourses within IDB areas, the cross sectional survey data would be beneficial to the developer. The developer should refer to the Developer Guidance (see section 5) and also consult with the IDB.

3.3.6 Structural Inspection Reports

The Environment Agency has provided structure inspection and diving reports for the following assets with accompanying drawings and photographs of the structures: Castle Mills Sluice, Harrold Middle Weir, Harrold Mill Weir and Harrold Top Weir.

3.3.7 Existing Flood Defences

The Bedford Group of IDBs maintain a number of flood defence structures within the Bedford Borough. The full list is given in Appendix C1. The list comprises flood storage areas, embankments, weirs, outfalls and sluices. The description of the structure is given along with information such as the owner/maintainer, residual life and condition.

The Environment Agency maintains a variety of flood defence structures throughout the Bedford Borough. These are recorded within the Environment Agency's National Flood and Coastal Defence Database (NFCDD). The structures include channels that are maintained in order to protect against fluvial flooding (e.g. revetments, raised walls etc) and man-made raised defences. Thorough descriptions of the structures are given including materials, dimensions, design levels and conditions. The condition analysis is based on the Environment Agency Condition Assessment Manual (Ref: 24).

The Flood Zone maps assume that all areas at risk of flooding are undefended, however where there are areas benefiting from defences up to an adequate standard these are shown on the Environment Agency published maps. The SFRA will detail the defended and undefended areas for all allocated developments that lie in areas at risk of flooding (Appendix A4 illustrates locations of flood defences and Appendix A5 illustrates the conditions of flood defence assets). These areas are subject to further detailed assessment and the conclusions of which can be found in section 4.2.

3.3.8 Development Plans, Policy and Guidance

The following Development Plans, Policy and Guidance documents have been provided to aid with the SFRA:

- Bedford Town Centre Area Action Plan (Ref: 2)
- Core Strategy & Rural Issues Plan (Ref: 3)
- The Bedford Water Cycle Strategy (Ref: 4)
- The East of England Plan (Ref: 11)
- Bedford Borough Local Plan 2002 (Ref: 12)
- Milton Keynes and South Midlands Sub-Regional Strategy (Ref: 13)
- The Marston Vale Surface Waters Plan (Ref: 14)

- Great Ouse Catchment Flood Management Plan (Ref: 25)

3.3.9 Existing Studies on Flood Risk

Bedford Town Centre Strategic Flood Risk Assessment

The Bedford TCAAP (Ref: 2) was completed in 2006 by WSP. The document examines the risk of flooding from: key watercourses, structures, flood defences, modelled flood levels, flooding mechanisms, historic flood levels, sewers, groundwater, drains, overland flows, and climate change. The information in this SFRA will complement the Bedford TCAAP and thus the two documents should be read in conjunction.

Kempston to Willington River Great Ouse Modelling

In 1993 HR Wallingford carried out a flood modelling study of a reach of the River Great Ouse from Kempston to Willington (Ref: 26). A range of design events were examined (see Table 4.2 of the report) and the extent of flooding commented upon (see Table 4.3 of the report).

Bedford Borough and Mid Beds District Outline Water Cycle Strategy

The Bedford Borough and Mid Beds District Outline Water Cycle Strategy (WCS) (Ref: 4) was finalised in February 2009 and undertaken by Halcrow and Hannah Reed on behalf of Renaissance Bedford. The report defines the flood risk zones, summarises existing flood risk, and outlines planned mitigation for major development sites and the downstream impact. The WCS includes the key aspects of these issues but goes into a greater degree of detail in relation to drainage solutions within allocated areas for development and Key Service Centres, SuDS and surface water management.

The details included within the WCS have not been repeated in this Level 2 SFRA and as such this SFRA should be read in conjunction with the WCS. In a number of locations this SFRA outlines key issues, but refers to the WCS for further detail.

Great Ouse Catchment Flood Management Plan

The Great Ouse Catchment Flood Management Plan (CFMP) (Ref: 25), hereafter referred to as the CFMP was completed by Royal Haskoning for the Environment Agency to produce a policy document for a catchment wide approach to flood risk management.

At the time of writing the 2007 version of the CFMP was available for this SFRA however this CFMP is currently being revised to ensure that the best available information is used to inform policies.

The evidence supporting version 1 of the CFMP was inadequate due to poor modelling and the area FCRM teams had no confidence in using the policies in order to help programme future strategies and flood defence schemes. Therefore no detail of information or policy has been taken from the 2007 CFMP and included within this SFRA.

The revised version of the CFMP is anticipated to be completed in July 2010.

3.4 Flood Mapping Data

Flood risk data for the Bedford Borough has been made available for this Level 2 SFRA from a number of sources as outlined in the previous sections. This section provides details on the information which has been used to produce the mapping which is presented in Appendix A and will be used for the application of the Sequential Test.

3.4.1 Data Analysis

Data analysis takes the form of Flood Zone mapping of various return period events, coupled with historical flood extents. The impact of climate change on these events have been assessed and accounted for in a series of figures. Potential sustainable mitigation options are discussed, making reference to the geology and topography of the area along with specific risk locations.

3.4.2 Data Mapping

Flood locations and extent mapping is available from a number of sources as listed below:

- Flood reports which cover the Bedford Borough catchment;
- Hydraulic modelling studies;
- Historical flooding events;
- The Environment Agency;
- The IDB; and
- Anglian Water data.

The information that has been obtained and mapped should be used by Bedford Borough to aid with the application of the Sequential Test.

3.4.3 Flood Zone Mapping

The Flood Zone mapping carried out for this Level 2 SFRA has been compiled using data from several sources including Environment Agency data and hydraulic modelling results. This Flood Zone mapping will form the basis of the Sequential Test and allows for designated development areas to be assessed in terms of flood risk at present and in the future. The various maps created for the Bedford Borough are included within Appendix A and are detailed as follows:

- Appendix A.1 holds the location map for the study.
- Appendix A.2 details the locations of the development allocations within the Adopted Bedford Borough Location Plan. The map does not include those development allocations that lie within the Bedford TCAAP and therefore already within the TCAAP SFRA.
- Appendix A.3 shows the locations of the Flood Zone 2 and 3.
- Appendix A.4 holds the information for the structures overview.
- Appendix A.5 holds the information for flood defence assets including a condition assessment.
- Appendix A.6 shows the Bedford IDB catchment, the watercourses they maintain and the assets that they maintain.
- Appendix A.7 holds the information for the Flood Warning overview.
- Appendix A.8 shows the hazard rating at the Key Service Centres. This rating is based on flooding probability, flood depth, flood velocity and the rate of onset of flooding.
- Appendix A.9 shows the mapping index for the detailed mapping that has been carried out.
- Appendix A.10 provides detailed mapping for the flood risk of the Bedford Borough, including Flood Zones, modelled flood outlines, historical flood extents and spot locations for flooding from IDB and Anglian Water.
- Appendix A.11 provides detailed mapping to show the assets and structures within the Bedford Borough. The detailed mapping also includes details of structures and assets maintained by the Environment Agency.
- Appendix A.12 provides detailed mapping to show recommended development types for the allocated development locations.
- Appendix A.13 provides an overview of areas that are susceptible to surface water flooding.

The maps have been created using the best available data at the time of writing. For the purposes of this SFRA the Bedford Ouse model was re-run with fluvial flows for the 4% and 1% AEP events and the 1% AEP with an allowance for climate change. It was not within the scope of this SFRA to

build additional modelling or carry out additional hydrology calculations and as such the 4% AEP hydrology was the best available data to represent the Functional Floodplain (PPS25 stated the Functional Floodplain would be represented by the 5% AEP). Hydrology for the 0.1% AEP event was not available, thus the Flood Zone 2 outline provided by the Environment Agency will be used for the River Great Ouse.

Flood Zones 2 and 3 provided by the Environment Agency will be used to determine Flood Zones associated with any tributaries or areas not represented in the Bedford Ouse model. This model reach is from Brackley to the tidal Ouse, however for the purpose of this SFRA only the reach within the Bedford Borough i.e. from Newton Blossomville to Eaton Socon was run. Neither the Functional Floodplain nor the 1% AEP with an allowance for climate change flood outlines were provided for this SFRA. Therefore the Functional Floodplain will be represented by Flood Zone 3 (this provides a conservative estimate of flood extent) and the 1% AEP with an allowance for climate change will be represented by Flood Zone 2 for the areas outside the Bedford Ouse model extent.

In addition to the Bedford Ouse model flood outlines, modelled flood outlines were produced for Harrold and the Bedford Valley Park area, where the Functional Floodplain, 1% AEP, 1% AEP with an allowance for climate change and the 0.1% AEP have been made available for this study. The Functional Floodplain has been represented by the 5% AEP and the 4% AEP in the Harrold and Bedford Valley Park models respectively.

The flood outlines produced by re-running existing models, and those made available for this Level 2 SFRA by the Environment Agency and other organisations have been merged to produce a single updated outline for the whole Bedford Borough. A number of models have been used to provide the flood outlines and in various locations there is not a smooth transition between outlines created by one model and those produced by another. It was not deemed appropriate to smooth this transition as this would have required engineering judgment rather than model results and therefore this accounts for the step like transition. A location example of where this occurs is in the Bedford Valley Park area at the downstream extent of the Scott Wilson Bedford Valley Park model (Ref: 19). At this location the flood outline extents are not consistent with the Bedford Ouse model outlines and as such as a step like join exists where the two outlines have been merged.

In addition to fluvial flood risk mapping the Environment Agency has made mapping available to Local Authorities which highlights areas that are susceptible to surface water flooding. This mapping is current at the time of writing but it is planned that the Environment Agency will update this mapping by summer 2010. There are a number of uncertainties associated with this mapping and as such the guidance (Ref: 27) states that the mapping should not be displayed at a more detailed scale the 1:50,000, thus the mapping within this SFRA provides an overview of areas susceptible to surface water flooding.

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4. Flood Risk

4.1 Sources of Flooding

4.1.1 Fluvial

Overview

The primary source of flood risk in Bedford Borough is fluvial. The River Great Ouse passes through the centre of Bedford and through many of the surrounding villages. In addition to the River Great Ouse there is a risk from the River Til and the Riseley and Pertenhall Brooks to the north of Bedford. The Elstow Brook to the south of Bedford also poses a flood risk. There are also numerous smaller watercourses and ditches that cross the Bedford Borough. Appendix A shows the location and flood risk (from Environment Agency Flood Zones) of these watercourses.

There is some risk of flooding in parts of the following built up areas:

- Bedford
- Kempston
- Bromham (Key Service Centre)
- Clapham (Key Service Centre)
- Sharnbrook (Key Service Centre)
- Harrold (Key Service Centre)
- Great Barford (Key Service Centre)
- Pertenhall
- Felmersham
- Oakley
- Great Staughton
- Wilden
- Riseley
- Radwell

The primary source of assessing fluvial flood risk is with the use of Environment Agency Flood Zones; Flood Zone 1 (Low Probability), Flood Zone 2 (Medium Probability), Flood Zone 3a (High Probability) and Flood Zone 3b (Functional Floodplain). Further details are provided within section 2.1.4.

This Level 2 SFRA requires Flood Zone 3 to be refined to Flood Zone 3a and 3b by utilising and improving the existing available hydraulic models. The Environment Agency has also updated their flood zone maps and these have also been incorporated into this SFRA where updated modelled outlines have not been made available. The delimitation of each Flood Zone has been given in section 3.4.3.

Detailed fluvial flood risk

The simulations run for Bedford River Valley Park model produced by Scott Wilson identify that the most significant areas that are at risk within the this modelled area are the Bedford sand and gravel pit; Priory Marina and residential development on Goodman's Close; and Cardington Road between Eastcotts Road and Mareth Road in the Fenlake area. The results of this model have no fluvial flood risk implications on the proposed development sites for residential or infrastructure development.

Detailed hydraulic modelling has been carried out for two un-named drains located within Harrold since the completion of the Level 1 SFRA. One of these un-named drains directly discharges into the River Great Ouse and the other into the River Great Ouse via the Harrold-Odell Country Park reservoir / lakes. The result is a refined Flood Zones 2 and 3 within Harrold such that less area is defined as at risk from flooding. This refinement reduces the extent of Flood Zones 2 and 3, a result of which will increase the development potential for Harrold.

In addition there have been updates in the Flood Zone 2 and 3 as provided by the Environment Agency since the completion of the Level 1 SFRA – two explicitly mentioned areas are Kemptson and the Wixams over which the Flood Zones have been refined. The revision in flood outline for

the Kempston area has resulted in 34 properties, including a number on Brook Drive, being removed from Flood Zone 3. The refined flood outline for the Wixams site is reduced such that areas of the industrial development are no longer located within Flood Zone 3.

For each of the Key Service Centres the flood depth, flood velocity and rate of onset have been taken from the available hydraulic models. The hydraulic models available for this assessment were the Bedford Ouse and the unnamed watercourses in Harrold. The flood attributes are presented in the following three tables, Table 4.1, Table 4.2 and Table 4.3.

The flood depth was taken to be the peak water depth above the lowest bank level.

The rate of onset was assumed to be the time taken for the water level to rise from the lowest water level at the start of the event (which represents baseflow within this model) to the time at which out of bank flooding occurs. Hydrographs which illustrate the change in flood level throughout the event, which includes the time at which out of bank flooding occurs, are included with Appendix D.

The flood attributes have been taken from the point within each key service centre where flood inundation occurs first. Two sets have been produced for Harrold because two hydraulic models were available for this service centre.

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Harrold (Harrold model) Grid Ref: 495118, 257142. Model chainage 298	0.12m	0.12m	0.13m	0.13m
Harrold (Bedford Ouse model) Grid Ref: 494850, 256220. Model chainage 84015	0.79m	0.91m	1.02m	The model was not run for this return period due to the lack of hydrology data
Clapham (Bedford Ouse model) Grid Ref: 502550, 252560. Model chainage 109725	1.02m	1.25m	1.52m	
Bromham (Bedford Ouse model) Grid Ref: 501550, 250980. Model chainage 114205	1.30m	1.60m	1.86m	
Great Barford (Bedford Ouse model) Grid Ref: 513550, 251660. Model chainage 135105	0.73m	0.97m	1.23m	

Table 4.1 – Flood Depth from lower bank level at each of the Key Service Centres

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Harrold (Harrold model) Grid Ref: 495118, 257142. Model chainage 298	0.25m/s	0.25m/s	0.25m/s	0.25m/s
Harrold (Bedford Ouse model) Grid Ref: 494850, 256220. Model chainage 84015	0.31m/s	0.31m/s	0.31m/s	The model was not run for this return period due to the lack of hydrology data
Clapham (Bedford Ouse model) Grid Ref: 502550, 252560. Model chainage 109725	0.89m/s	0.89m/s	0.90m/s	
Bromham (Bedford Ouse model) Grid Ref: 501550, 250980. Model chainage 114205	0.33m/s	0.33m/s	0.34m/s	
Great Barford (Bedford Ouse model) Grid Ref: 513550, 251660. Model chainage 135105	0.59m/s	0.60m/s	0.60m/s	

Table 4.2 – Flood velocity at the Key Service Centres

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Harrold (Harrold model) Grid Ref: 495118, 257142. Model chainage 298	6 hours, 50 mins	6 hours	5 hours, 40 mins	5 hours, 10 mins
Harrold (Bedford Ouse model) Grid Ref: 494850, 256220. Model chainage 84015	11 hours, 20 mins	11 hours	10 hours, 50 mins	The model was not run for this return period due to the lack of hydrology data
Clapham (Bedford Ouse model) Grid Ref: 502550, 252560. Model chainage 109725	16 hours, 20 mins	14 hours, 10 mins	13 hours	

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Bromham (Bedford Ouse model) Grid Ref: 501550, 250980. Model chainage 114205	14 hours, 30 mins	12 hours, 20 mins	11 hours, 30 mins	
Great Barford (Bedford Ouse model) Grid Ref: 513550, 251660. Model chainage 135105	23 hours	17 hours, 40 mins	15 hours	

Table 4.3 – Rate of flood onset in the Key Service Centres

Note that flood attributes have not been given for four Key Service Centres, Sharnbrook, Wootton, Stewartby and Wilstead, as these settlements are not contained within the flood outlines produced from the Bedford Ouse model. No hydraulic modelling for watercourses in close proximity to these Key Service Centres were made available at the time of writing. This SFRA makes use of the best available data and as such it was not possible to determine flood attributes with these three Key Service Centres, as there was no hydraulic modelling available.

These attributes are used to determine the flood hazard to each of the Key Service Centres using the Hazard to People Classification Rating taken from the Environment Agency Supplementary Note of Hazard Rating (Ref: 28). The flood hazard to the area is defined in four grades from 'very low hazard' to 'danger for all' based on a factor between flood velocity and flood depth. The grading system and classification can be seen in Table 4.4 which was taken from Table 2 in the Supplementary Note. The table used to produce the classifications for each Key Service Centre can be seen in Appendix E.

Threshold for Flood Hazard Rating	Degree of Flood Hazard	Description
< 0.75	Low	**Caution** – Flood zone with shallow flowing water or deep standing water.
0.75 < 1.25	Moderate	**Dangerous for some (i.e. children)** – Danger, flood zone with deep or fast flowing water.
1.25 < 2.0	Significant	**Dangerous for most people** – Danger, flood zone with deep fast flowing water.
> 2.0	Extreme	**Dangerous for all** – Extreme danger, flood zone with deep fast flowing water.

Table 4.4 – Hazard to People classification

This hazard rating for has been produced for one location for each of the Key Service Centres which is shown in Appendix A8 for the 1% AEP event. To produce a more comprehensive hazard map that details the hazard rating for all areas at risk from fluvial flooding within the Key Service Centres then a 2D model would be required. A 2D model was not built for this Level 2 SFRA as a hydraulic model build was not within the scope of this assessment.

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Harrold (Harrold model)	0.58	0.58	0.58	0.58
Harrold	1.60	1.67	1.75	The model

Key service centre	Functional Floodplain	Flood Zone 3	Flood Zone 3 + Climate Change	Flood Zone 2
Clapham	2.40	2.50	3.25	was not run for this return period due to the lack of hydrology data
Bromham	1.94	2.20	2.40	
Great Barford	1.80	2.00	2.13	

Table 4.5 – Hazard rating for each Key Service Centre

The hazard ratings for the Key Service Centres appears to be high, but it should be noted that in the case where 2D modelling is not available hazard ratings are limited to spot locations. These locations are in close proximity to river banks and in all cases does not represent hazard to any current development. It is therefore necessary that 2D modelling is carried out to provide a realistic hazard rating to each of the Key Service Centres.

4.1.2 Surface Water

Surface water flooding has the potential to contribute a significant flood risk in urban areas due to the rapid runoff rates associated with urban land use and the volume of water that flows into the sewer systems in a relatively short space of time.

Flooding of sewers can occur when the artificial drainage is overwhelmed hydraulically, becomes blocked, or suffers structural failure or pump failure. Blockage and structural failure incidents tend to be isolated and unpredictable and therefore inappropriate for a strategic level analysis.

A review of areas where the sewer system has been overwhelmed can potentially identify limited capacity of the drainage system or where the system does not provide an adequate level of service.

Anglian Water has provided their DG5 register which details locations of surface water and foul water flooding which has been updated since the production of the Level 1 SFRA. Due to new policy within Anglian Water it is not possible to provide detailed locations of identified flooding areas at a street level (see section 3.3.3 for further detail). Areas which have previously experienced foul and surface water flooding from the Anglian Water system are Clapham, Kempston, Bedford and Oakley as identified in the DG5 register. Table 4.6 provides details of sewer flooding as included within the DG5 register for the Bedford Borough area (excluding those within the Bedford TCAAP).

General location	Source of flooding	Number of locations
Bedford	River, combined sewer, foul sewer, surface water, foul and surface water. Some sources of flooding are unknown	10
Clapham	Foul sewer	9
Kempston	Surface water, foul sewer, surface water sewer, possible cross connection with surface water	15
Oakley	Foul (or river)	2

Table 4.6 – Anglian Water's DG5 register: Locations and sewer type

In addition, development has the potential to cause an increase in flood risk as a result of increasing impermeable areas, thus leading to a faster runoff rate following rainfall events. PPS25 states that a development proposal must ensure that the volumes and peak flow rates of surface water leaving the site are no greater than the rates prior to the proposed development (i.e. greenfield rates) unless specific off-site arrangements are made and result in the same effect. The later is becoming increasingly possible, as this often more strategic approach forms the ethos of

SWMPs (discussed further in section 5.4.3). The SWMP will asses flood risk from the following sources:

- Pluvial sources – flooding as a result of high intensity rainfall which has not entered underground drainage networks or watercourses possibly as a result of blocked or under capacity networks;
- Sewer sources – when the capacity of underground drainage networks is insufficient resulting in surcharging or flooding within buildings;
- Urban channels – flooding from small open channels or culverted channels which receive the majority of their flow from urban areas; and
- Overland flows – when flooding occurs as a result of overland flow including flows from groundwater springs.

For the purposes of the WCS approximate storage volumes and permitted runoff rates for Bedford Borough's employment allocation in the Northern Marston Vale have been calculated using the industry standard approach (Ref: 29 and 30). It was calculated that the greenfield runoff rates for a 21ha requirement are 130l/s, 320l/s and 450l/s for the 50% AEP, 5% AEP and 1% AEP events respectively. A long term storage facility for the development would require storage for 5,300m^3 from which the discharge would be maintained to a level of 2l/s/ha.

In addition the greenfield runoff rates for the area granted planning permission at the Wixams, which covers and area of 81.3ha are calculated to be 200 l/s, 600 l/s and 900 l/s for the 50% AEP, 3.3% AEP and 1% AEP events respectively. Further details relating to surface water flooding can be seen in the WCS (Ref: 4).

Defra have recently announced a further wave of funding for Local Authorities in terms of Surface Water Flooding (Ref: 31). As part of this, Defra have produced a list of prioritised areas. The Environment Agency has commissioned maps to show areas in England that are susceptible to surface water flooding following a very severe rainfall event (see Ref: 27 for a detailed methodology). This information was provided to local resilience forums for emergency planning purposes. This information is the best source of currently available information. The resulting maps were produced on a national scale and work is under way to produce a more detailed and refined set of maps. According to the information produced by Defra, Bedford Borough has over 5,000 properties that are at risk from surface water flooding (see Table 4.7, below). All of the Key Service Centres (highlighted in Table 4.7 as bold text) have been identified as having properties at risk of surface water flooding, creating a total of approximately 1,300 properties at risk from surface water flooding within the Key Service Centres.

Settlement Rank	Settlement Name	Estimated Number of Properties at Risk
99	Bedford	3400
580	**Great Barford**	**470**
696	Kempston	350
947	Riseley/Top End	220
1054	**Bromham**	**180**
1227	**Harrold**	**140**
1247	**Clapham (Bedford)**	**130**
1276	**Wootton (Bedford)**	**130**
1455	**Wilstead Industrial Estate**	**100**
1715	Wilshamstead	70
2306	Willington (Bedford)	30

Settlement Rank	Settlement Name	Estimated Number of Properties at Risk
2557	Turvey	20
2587	**Stewartby**	**20**
2602	Cardington	20
2987	Cople	Less than 10
3087	**Sharnbrook**	**Less than 10**
3119	Milton Ernest	Less than 10
3235	Shortstown	Less than 10
3387	Oakley (Bedford)	Less than 10
3658	Chellington	Less than 10
4097	Pavenham	None Identified
Total No. of Properties at Risk (approx.)		**5,280**

Table 4.7 – Areas prone to Surface Water Flooding in Bedford as defined by DEFRA (Ref: 31)

It is recommended that the areas listed in Table 4.7, above, are analysed in further detail as part of the Surface Water Management Plan which should include an update to the Marston Vale Surface Waters Plan.

In addition the Environment Agency has made mapping available to Local Authorities which identifies areas susceptible to surface water flooding. This mapping has been produced using a simplified method that does not take into account the presence of underground sewerage and drainage systems, small over ground drainage systems or buildings. Thus the mapping provides a generalised assessment of location which are more likely to be susceptible to surface water flooding. Due to the simplistic nature in which these maps have been produced they should not be used as the sole evidence for planning applications decisions without further supporting evidence nor to identify surface water flood risk to individual properties. It is proposed that the purpose of including this mapping within the SFRA is to identify areas where it is highly important that further assessment is required to determine surface water flood risk for the purposes of SWMPs and FRAs. Further guidance relating to this mapping can be seen in the guidance document produce by the Environment Agency (Ref: 27).

Appendix A13 provides an overview of areas that are susceptible to surface water flooding within the Bedford Borough. Specific attributes are not given to the category of susceptibility, however those that are identified to be 'More Susceptible' have a natural vulnerability to flood first, deepest and/or flood relatively frequently.

Detailed Environment Agency mapping displaying the susceptibility of the Key Service Centres to surface water flooding can not be given within this SFRA due to licensing agreements, however an overview is given below:

Harrold – Within and surrounding Harrold are areas that are susceptible to surface water flooding, particularly along the interconnecting drains and to the south of the developed area. It is highly advisable that further assessment of surface water flood risk is carried out for Harrold and the immediate vicinity to more accurately identify areas at risk from surface water flooding.

Sharnbrook – The majority of Sharnbrook has not been identified to be susceptible to surface water flooding, with the exception of the areas in close proximity to the Sharn Brook and its tributaries. There are also a few small pockets of areas classified as 'Less Susceptible' to surface water flooding in the southern areas of Sharnbrook.

Clapham – Approximately half the developed area of Clapham is identified to be within areas classed as 'Less Susceptible' or 'Intermediate Susceptibility'. Generally these areas are located in close proximity to tributaries of the River Great Ouse, however not exclusively. It is therefore

highly advisable that further assessment of surface water flood risk is carried out for Clapham to more accurately identify areas at risk from surface water flooding.

Bromham – In general it can be identified from the mapping that Bromham is at a low risk from surface water flooding with the exception of areas along the watercourse, and in particular along Bromham Brook. In addition to these areas there are also a few small pockets of areas classified as 'Less Susceptible' to surface water flooding.

Wootton – Areas classed as 'Intermediate Susceptibility' and Less Susceptible' are located within Wootton. These generally follow the minor watercourses however there are also areas away from the watercourses which are at risk. It is advisable that further assessment is carried out with the aim to more accurately determine areas that are at risk from surface water flooding.

Stewartby – The areas which have been identified to be susceptible to surface water flooding within Stewartby are generally, although not exclusively, located in and around the Broadmead Business Park and to the north of the development area.

Wilstead – It has been identified from the mapping that Wilstead is generally 'Less Susceptible' to surface water flooding, however there are pockets which are not classed to be susceptible to surface water flooding and pockets which are classed to be at 'Intermediate susceptibility'. Due to the spatial extent of areas with differing susceptibility it would advisable that further assessment is carried out to produce a more accurate representation of flood risk to Wilstead.

Great Barford – It has been identified that Great Barford is at a significant risk from surface water flooding particularly along the tributary to the River Great Ouse. There are wide expanses of areas that are at an 'Intermediate Susceptibility' with a number of areas classed as 'More Susceptible'. In addition there are also areas to the south away from the watercourse which are classed as 'Less Susceptible'. Due to the widespread identification of areas susceptible to surface water flooding it would be advisable that more detailed assessment is carried out to identify areas at risk from surface water flooding within Great Barford.

4.1.3 Groundwater

Groundwater flooding is the emergence of groundwater at the ground surface or into subsurface voids arising as a result of:

- abnormally high groundwater heads or flows;
- the introduction of some obstruction to groundwater flow; or
- the rebound of previously depressed groundwater levels.

It most commonly occurs in unconfined aquifers, either major aquifers from which considerable amounts of water can be discharged or in shallow permeable sediments. Locations are typically near areas of natural groundwater discharge such as river valleys and spring lines. However, it can also arise from artesian flow from confined or semi-confined aquifers and in any location where an obstruction of groundwater flow causes an abnormal increase in groundwater heads.

Groundwater flooding usually occurs following a prolonged period of low intensity rainfall. The flooding may continue for long periods of time, typically weeks or even months, because groundwater flow is much slower than surface flow and thus water levels take a relatively long time to recede.

Catchment Description

Bedford Borough is predominantly underlain by the Oxford Clay and Kellaways Beds. Upstream of Bedford the River Great Ouse valley has eroded the Oxford Clay exposing the Great Oolite Group. The sequence of Oxford Clay and Kellaways Beds is characterised by low permeability, though the thin Kellaways Sand member is recognised in places as a minor aquifer. The Great Oolite Group beneath this comprises a mixed succession of clays, siltstones and limestones. From the base of the Group the recognised formations are the Rutland Formation, the Blisworth Limestone, the Blisworth Clay and the Cornbrash. The Cornbrash formation and Blisworth

Limestone (formerly Great Oolite Limestone) are classed as minor aquifers (Jones *et al*., 2000, Ref: 32).

Superficial deposits overlie a large proportion of the Bedford Borough. The most widespread superficial deposit is the glacial till, predominantly an unstructured clay with a variable component of coarser material within it. Along the river valleys there are river terrace deposits which comprise sands and gravels. The superficial deposits may form minor aquifers where they are permeable, e.g. sands and gravels, but where they have lower permeability, e.g. the glacial till, this will impede the flow of water.

The topography of the Bedford Borough is generally fairly flat with land rising in the north with lower land to the south. The River Great Ouse valley is the dominant topographic feature.

Groundwater Flood Risk

There is limited data available to assess the flood risk to Bedford Borough from groundwater. A large proportion of the Bedford Borough is situated on the Oxford Clay and Kellaways Beds, the Great Oolitic Group, and glacial till. None of these are major aquifers, that is, they lack the potential to store and transmit large quantities of water, and consequently the risk of groundwater flooding is considered to be low. The area where groundwater flood risk is considered higher is where the river terrace deposits are present in the river valley, as within these sands and gravels high water tables can be experienced.

In a valley setting, groundwater flooding and fluvial flooding are likely to be linked if water in the sands and gravels of the river terrace deposits is in hydraulic connection with the river. The CFMP (Ref: 25) reports that groundwater can add to the flow of a river, though it is not thought the have a notable influence on fluvial flooding in the Great Ouse catchment. It is more likely to affect low lying areas of land and urban areas where there are cellars and basements.

The Environment Agency, Bedford Borough Council and the IDB have no records of historical groundwater flooding incidents in the Bedford Borough. The Great Ouse CFMP (Ref: 25) does not identify any historical occurrences of groundwater flooding within the Bedford Borough area. These records cover recent periods of heavy rainfall, such as winter 2000/01 and summer 2007, when groundwater flooding was experienced in many parts of the country.

There is a reported incidence of groundwater flooding near the village of Keysoe during 2000-2001 (Ref: 33), however no other information has been supplied to verify this. There is uncertainty as to whether this was a genuine groundwater flood event or a misreported pluvial flood event combined with poor surface water drainage, so this occurrence should be viewed with caution (pers. comm. Environment Agency, September 2009).

In the WCS (Ref: 4) it is stated that even though there are areas to the south east and south west of Bedford that are known to be partially waterlogged, there are no details of historical groundwater flooding on record for the Bedford Borough.

During the first stage of this SFRA the IDB identified areas that apparently lie very wet and it was considered this may possibly be due to high water tables. These areas included the villages of Wilstead, Cotton End and Cardington, and the Kempston area. In the latter there have apparently been recent problems with waterlogged gardens. These areas have been investigated by analysing the geology and topography at a strategic scale.

The Kempston area and the village of Cardington are sited on the river terrace deposits in the River Great Ouse valley. As mentioned above, it is on these deposits, due to their permeable nature that high water tables may be present.

The villages of Wilstead and Cotton End (and also Keysoe) are sited on the Oxford Clay and Kellaways Beds, with no overlying superficial deposits. Due to the relatively low permeability of this material, groundwater flood risk is considered low. Other factors such as local topography and surface drainage may provide an explanation for why these areas are reported to lie wet.

Groundwater Emergence Maps were produced as part of a Defra research project (Ref: 31) and set out to provide information on the scale, distribution and nature of groundwater flooding in England. The maps have been produced at a scale suitable for national assessment and, as

such, do not pinpoint sites where groundwater flooding will occur. Instead, they define broad areas of risk based on geology and topography. The Groundwater Emergence Maps do not imply flooding per se, only that groundwater would emerge at the surface first within the indicated areas. Where no flooding was reported, or information was not made available, the maps indicate estimated areas based on anticipated groundwater levels using relevant aquifer properties. Where no groundwater contours are available or the aquifer is of local significance only, the Base Flow Index derived from the Hydrology Of Soil Types (BFIHOST) classification colour coded network gives some indication as to the proportion of flow derived from baseflow.

On these indicative maps Bedford Borough is not marked as a groundwater emergence area. This is partly because there was no specific groundwater data available as this area is not underlain by a major aquifer. However, the Bedford Borough was classified based on the BFIHOST classification, and was given the lowest indicative groundwater flood risk category mapped (BFIHOST <0.7).

It is important to recognise the risk of groundwater flooding is typically highly variable and heavily dependent upon local geological, topographical and weather conditions, as well as local abstraction regimes. Groundwater flooding is hard to predict and challenging to mitigate. Even with a carefully monitored network of boreholes, it can be difficult to tell when and where groundwater flooding will occur. It is not possible to sensibly develop a strategic map of 'groundwater risk' as part of the SFRA process, and it is important to recognise that historical flooding is not a robust measure of the risk of flooding in future years.

4.1.4 Canal Infrastructure

There are no canals that flow through the Bedford Borough and therefore there is no flood risk from canal infrastructure.

There are proposals to construct a section of canal from Milton Keynes to Bedford, which would link the Grand Union Canal to the River Great Ouse. These proposals have not been considered as part of this SFRA. Should the proposals for this canal system go ahead site specific FRAs will be required for submission with the planning application.

4.1.5 Reservoirs and Other Water Bodies

Flooding from reservoirs can occur when water retaining structures fail. All large reservoirs are covered by the Reservoirs Act 1974 and are subject to regular safety inspections. A very low residual risk from these reservoirs remains if they were to fail unexpectedly, however this is considered a risk that is managed by the operating authority and/or owner i.e. water companies or the Local Authority.

There are several balancing lakes within the Bedford Borough and whilst the list below is not an exhaustive list the most significant are located as follows:

- Thurne Way – Bedford
- Douglas Road – Bedford
- Chantry Road – Kempston
- Woburn Road – Bedford
- Marsh Leys
- The Wixams
- Great Barford
- A6 Park and Ride
- Interchange Retail Park
- Mowsbury/Cleat Hill

There are also a number of proposed reservoirs/balancing ponds which would be located at proposed development sites in Cardington.

From the data collected during this SFRA, there is no evidence of historic flooding from any of the above reservoirs and balancing lakes. It has been assumed that there is no flood risk from these balancing lakes as long as they are maintained to a good standard. Breaching and overtopping scenarios should be carried out for site specific FRAs, as required.

Anglian Water has confirmed that they will be adopting a closed balancing facility at Acacia Road in Bedford.

Due to the complexity of locating all balancing facilities within the Bedford Borough and the low flood risk associated with them at a strategic level, the risk of flooding from existing and proposed individual ponds/systems should be addressed within site specific FRAs.

In addition to the balancing lakes is Stewartby Lake which is classified as a category D (WCS Ref: 4) reservoir under the Reservoirs Act 1974. A reservoir is classified as category D when a breach will not cause any foreseen loss of life and there would be limited additional flood damage (Floods and Reservoir Safety, Ref: 34). A category D reservoir would be constructed for the design 0.75% AEP year flood inflow. Thus this reservoir is seen to have a very low flood risk at present due to lack of development in front of the reservoir dam.

4.2 Flood Defence and Structures

For the purposes of this SFRA, the Environment Agency and the IDB have provided information on their flood defence structures and assets within the Bedford Borough area.

4.2.1 IDB Maintained Structures and Flood Defences

Since the completion of the Level 1 SFRA there has been one update to the information provided by the IDB (See Appendix C1). The update is that the flow control structure requiring urgent attention (which is located at Great Barford on Green End Road) has since been repaired. As such, at the time of writing, there are no IDB structures which required urgent repair work.

The most note worthy structures maintained by the IDB, i.e. the structures which should they fail result in the greatest consequences, are the flood storage areas and defences located in Great Barford and in the Elstow catchment. According to the information provided by the IDB, these structures are defined as having a residual life of at least 30 years, although in most cases they would have a 50 year life and therefore there is no urgency for repair work. For further details see Appendix C1.

The IDB also identifies that the watercourse channels and their conveyance capacity area are an important part of the flood risk management system. These are categorised as 1, 2, and 3, where maintenance works such as weed cutting and dredging are carried out yearly, every two to five years, and greater than five years, respectively (see Appendix C1).

4.2.2 Environment Agency Maintained Structures and Flood Defences

The NFCDD database has been used to produce a list of all flood defences within the Bedford Borough, which are included with Appendix C2. The most significant defences are maintained by the Environment Agency, where the consequences of failure would be greatest are located within Bedford town centre thus are covered by the TCAAP (Ref: 2) and details of which are not repeated here.

The Environment Agency has supplied the available structure inspection reports for two of their structures in the Bedford Borough – Castle Mills (Ref: 35) and Harrold Weir and sluice complex (Ref: 36). These reports and inspections were carried out between 2001 and 2003, more recent inspection reports were not available. The Harrold Weir complex and the Castle Mills sluice are both Environment Agency owned and maintained structures. It is assumed, based on the most up to date information available for this SFRA, that these structures with their regular planned maintenance regimes will not be allowed to fall in to disrepair and pose heightened flood risk.

Flood Defences

Assets have been graded using the Environment Agency Condition Assessment Manual (Ref: 24), which rates assets on a five scale grading system. Table 4.8 provides details of the various properties attributed to each of the five grades.

Grade	Rating	Description
1	Very Good	In good working condition, fully serviceable, no remedial work required. Maintenance to continue as present. No significant defect
2	Good	Minor defects, non urgent. Minor routine maintenance work required. In reasonable condition, some increase in maintenance needed, probably not more than 5% affected with slight defect.
3	Fair	Some cause for concern, requires careful monitoring. Significant maintenance works required. Average condition, some minor repairs needed and moderate 5-20% affected.
4	Poor	Structurally unsound now or in the near future. Major remedial works required or replacement (1-5 years). Extensive repair required in short term. Extensive defect 20-50% affected.
5	Very Poor	Completely failed or derelict, requires complete reconstruction. Major urgent repairs or replacement needed without delay to avoid failure probably beyond repair. Extensive defect >50%.

Table 4.8 – Asset grading system (Ref: 24)

The assets were last inspected between 2005 and 2008. The general condition of the flood defence structures is good with 14 Environment Agency structures receiving a condition grade of 1 or 2, such that these structures are in good condition requiring only routine repairs and maintenance. Six Environment Agency structures had an overall rating of 2 but have a worst condition of 3. None of the flood defence assets were considered in poor condition or were in need of urgent repairs at time of inspection.

4.3 Flood Risk sensitivity

The following section details the potential risk of flooding due to climate change, increase in urban land use and changes in land management practices as well as an outline of how to deal with runoff from urban areas.

4.3.1 Climate Change

PPS25 and other Planning Policies, such as PPS1 ‘Delivering Sustainable Development’, clearly recognise the need for future growth to consider the impacts of climate change to ensure development is undertaken in a sustainable manner.

Future climate change in England will impact upon both sea levels (which are anticipated to rise), and rainfall intensities (which are anticipated to intensify). Detailed figures on climate change allowances taken from Tables B.1 and B.2 of PPS25 respectively are given in Table 4.9.

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%	+20%		
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

Table 4.9 – Climate change allowances taken from PPS 25

Within the Bedford Borough existing properties currently at risk of flooding would therefore be at an increased risk due to climate change and further properties in areas that are not currently at risk may be prone to flooding in the future.

For the majority of the Bedford Borough a flood outline was produced for the 1% AEP event with an allowance for climate change through simulation of the event using the Bedford Ouse model. For areas not covered by the Bedford Ouse model and where additional modelling has not been provided (i.e. Harrold, Bedford Valley Park and Elstow if it is made available) the 0.1% AEP flood outline has been used as a surrogate for the 1% AEP plus climate change outline. This assumptions was defined and agreed within Bedford Borough Council, the Environment Agency and the Bedford Group of IDBs, at the SFRA start up meeting 11th January 2008 (Ref: 37).

In reference to the Flood Zone mapping (Appendix A.10) the impact of climate change in the Bedford Borough is:

- generally minimal and limited to narrow band slightly wider than the current 1% AEP outline;
- in most areas where there is significant risk the land use is rural;
- significant over the industrial area between Elstow and Wilstead; and
- relatively significant to a number of properties in Great Barford.

However neither the industrial site nor Great Barford (the area at an increased risk due to climate change) are included within the hydraulic models available for this SFRA. These areas have been identified using the 0.1% AEP outline to represent 1% AEP outline with an allowance for climate change. Thus if additional modelling was carried out, it is possible the climate change outline would be refined reducing risk in some areas. It was not in the scope of this SFRA to carry out such additional modelling.

The only climate change scenario available for this SFRA is the 1% AEP event. Flood outlines for climate change scenarios for other return periods were not made available and it was not within the scope to carry out additional modelling or hydrology to produce additional outlines.

The future risk from groundwater is more uncertain than surface water as the climate change predictions indicate that although sea levels will rise, thus possibly raising groundwater levels, overall summer rainfall will decrease, therefore having a long term effect of lowering the groundwater levels. However, long periods of wet weather, such as those experienced in the autumn and winter of 2000/2001 are predicted to increase based on the UK Climate Projections 09 (UKCP09). For further details refer to Ref: 38. These are the type of weather patterns that can cause groundwater flooding to occur. Thus determining the effect climate change will have on groundwater flooding is uncertain. SFRAs and FRAs should take into account climate change as outlined in PPS25 guidance (Ref: 8).

4.3.2 Increased Urban Development

The impact of increased urbanisation, if uncontrolled, is likely to create an increase in flood risk. Storm runoff from impervious surfaces, routed rapidly by artificial drainage networks can increase

flood peaks in watercourses downstream of new urbanised areas. There is also an increased risk of localised 'flash flooding' during intense rainstorms. Urban growth will therefore increase surface water runoff rates and volumes if not properly controlled.

However, new developments are unlikely to increase surface water flood risk for the following reasons:

- Some new development is likely to be located on 'brownfield' sites. These sites will already have connections to the drainage network. Therefore, generally unless the land use significantly increases the impermeable surface area, new development is unlikely to increase surface water flood risk. There is an exception to this, whereby low density residential areas of large houses, with extensive gardens, are replaced with high density developments of flats or smaller houses. The exception to this is where the drainage systems already in situ in brownfield developments will be older and less likely to meet the stringent requirements of current design standards. For this reason, it is expected that developers will actively demonstrate a betterment in surface water runoff through the use of Sustainable Drainage Systems (SuDS) and other mitigation techniques so that these potential adverse effects can be avoided.
- Previously any 'greenfield' allocations, surface water discharges from any new developments into watercourses would be controlled by the planning authority with technical leadership and guidance from the Environment Agency and the IDB to ensure that the existing greenfield runoff rates are maintained post development. This responsibility has changed to upper tier local authorities following the publication of the Flood and Waters Management Act. This can be achieved through on site mitigation to throttle runoff rates to the greenfield rate, however it is possible that a strategic approach will emerge as the preferred option through the completion of SWMPs and as such the development is likely to required connection to an existing drainage network. In addition to this, developers would have to approach Anglian Water to determine if they have the capacity to allow new development to connect to the drainage system. Anglian Water would either allow the connection if capacity allows, or they would inform the developer that an increase in capacity is required. The developer would then be required to cover the costs of increasing the capacity prior to development taking place and allowing connection to the Anglian Water system.
- Any additional development as permitted within PPS25 i.e. only developments classed as 'water compatible' or 'essential infrastructure' carried out in the Functional Floodplain may lead to an increase in flood risk and require further mitigation. The Functional Floodplain has been determined for the areas covered by the Bedford Ouse model and the additional small scale models (Harrold, Bedford Valley, Riseley and Elstow). Elsewhere a conservative approach of using Flood Zone 3 to represent the functional floodplain has been implemented. This could be further refined during the completion of site specific FRAs as it is possible that areas currently stated to be within the Functional Floodplain are in reality not inundated by flood water in the 5% AEP event, thus effecting potential development type.

Section 4.3.3 below identifies surface water mitigation options in the event that surface water flood risk is increased.

4.3.3 Potential Sustainable Mitigation

The form and function of SuDs to be used within a development, is heavily dependent on catchment characteristics. The topography and geology of the area will determine which form of SuDs would be most beneficial for the site; whether to assist the movement of water through infiltration, or to store excess flows. Table 4.10 details the types of SuDs options that could be developed within Bedford Borough.

SuDs Component	Utilisation on Development Site
Infiltration	Porous paving can be used for the majority of hardstanding areas. Where possible this should incorporate full infiltration. The use of soakaways and deep infiltration systems is not suitable for areas where shallow groundwater levels exist (<2m from ground level).
Subsurface Storage	This could be utilised alongside outflow controls to attenuate surface water during heavy storms, reducing peak flow rates significantly.
Retention Ponds/Detention Basins	If the size of the development site permits this method can be utilised, however, there are health and safety risks regarding open water.
Wetlands	This would be dependent upon the size of the development. It is acknowledged that many of the developments will not be able to use this SuDs method.
Green Roof	Dependent upon the type of development green roofs may be feasible and should be considered.
Swales	Green space on a development site could be limited and the land take required for 'optimum' swale geometry may prevent their use on many developments. The location and topography may also prevent the use of Swales.

Table 4.10 – SuDs Options that may be utilised within Bedford Borough

Opportunities for SuDs that use infiltration may be limited in areas for a number of reasons: there is a low permeability of soil; the water table is shallow; the groundwater under the site may be at risk; there is a potential for land contamination; and the infiltration of water in to the ground may adversely affect ground stability. A majority of the Bedford Borough has an underlying geology of Oxford Clays and only some areas are exposed by the more permeable Great Oolite. It is recommended that any site specific developments that may utilise SuDs infiltration techniques should be subject to thorough ground investigations to determine if infiltration techniques are suitable for the site.

4.3.4 Land Management

In addition to urban areas, management of agricultural land is also necessary to manage flood risk. It is necessary to manage agricultural land in relation to surface water runoff and sediment generation as agricultural practices, such as intensive livestock grazing which can lead to soil compaction, growing of crops that cover less of the soil surface which can promote soil erosion, the removal of hedgerows and woodland areas, reshaping the landform and the provision of positive land drainage can all result in an increase in flood risk downstream.

The Great Ouse CFMP outlines a number of potential scenarios that the catchment may experience. Agricultural decline and intensification of practices, dependent upon a number of pressures and drivers of economic change, could occur within the area. In addition it is also possible that changes to farming subsidies and the increased pressure for more sustainable farming practices will lead to areas of agricultural land becoming available for other purposes, including flood storage and conservation. These scenarios would alter the land drainage character of the catchment.

The Environmental Stewardship Scheme is a new agri-environmental scheme replacing the Environmental Sensitive Areas and the Countryside Stewardship Scheme. The Environmental Stewardship Scheme provides funding to farmers and other land managers in England to deliver effective environmental management of their land which can potentially mitigate flood risk. Opportunities provided by the Environmental Stewardship scheme which could potentially mitigate flood risk include the creation of multifunctional wetlands or conservation of arable land to grass land. Within the Environmental Stewardship Scheme there are three streams, including the Higher Level Stewardship which targets highest priorities and areas, under which flood risk falls. There are two flood risk objectives within the Environment Stewardship Scheme;

1. Make land 'available' for flooding

2. Implement resource protection measures that will reduce the likelihood of localised flooding incidents

These are likely to be achieved by encouraging options that reduce surface water runoff and/or promote storage of floodwater.

The meeting that took place on 11th January 2008 (Ref: 37) highlighted the fact that the Bedford Borough area would be subject to an increased area of woodland as the Forest of Marston Vale seeks to increase its woodland cover to 30% of the identified forest area by 2030.

There are also policies in place to ensure that the Bedford Borough meets its target level of woodland cover, as detailed below:

- East of England Plan RRS14 - Policies ENV1 and ENV4
- Bedford Borough Council - Local Plan Policies S5, NE21, NE22 & NE23
- Core Strategy & Rural Issues Plan policies CP22 and CP24

5. Developer Guidance

5.1 Generic Developer Guidance

The developer should consult various documents when considering developing in an area. These documents are outlined in the following sections.

This section aims to guide the developer through the use of the SFRA and also explains the requirements and the level of detail required in the site specific Flood Risk Assessment (FRA). It also provides guidance for the types of development appropriate within each of the Flood Zones, as well as additional guidance for developing in undefended and defended floodplains and information on how to raise floor levels and provide compensatory storage if required. Guidance on the Surface Water Drainage Assessment and Appropriate Mitigation Measures is also detailed in this section.

When developing a site it is important that developers have early discussions with the Environment Agency and/or the IDB to ensure that any site specific requirements are highlighted at the earliest possible stage. This will lead to a more efficient application process.

Applications are reviewed by the Council Development Control Team and as such guidance will be incorporated to help them assess windfall applications. A developer checklist which should be used by both developer and the development control team is included within Appendix G of the WCS (Ref: 4).

Factsheets have been produced for each of the Key Service Centres to allow a quick reference to interested parties on flood risk within each of the areas. In addition a factsheet has been produced outlining surface water management and proposed recommendations for a Surface Water Management Plan for the Bedford Borough. These are included within Appendix G.

5.1.1 How to Use the Strategic Flood Risk Assessment

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

A developer should consider flood risk issues at a site as early as possible. The SFRA can be used to provide an indication of the likely flood risk issues at a site from all sources of flooding. Developers should identify whether the development site has been allocated for that type of land use in the Local Development Documents or the Local Plan.

5.1.2 When is a Flood Risk Assessment Required?

A FRA will be required to accompany planning applications for:

- any development proposals of 1 hectare or greater in Flood Zone 1
- any development proposals in Medium Probability Flood Zone 2
- any development proposals in High Probability Flood Zone 3

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

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

5.1.3 Standard Flood Risk Management Guidance for Developers

The broad aim of the PPS25 is to reduce the number of people and properties within the natural and built environment at risk of flooding. To achieve this aim, planning authorities are required to ensure that flood risk is properly assessed during the initial planning stages of any development.

Responsibility for this assessment lies with developers and they must demonstrate the following:

- Whether the proposed development is likely to be affected by current or future flooding from any source;
- Whether the proposed development will increase flood risk elsewhere; and
- Whether the measures proposed to deal with any flood risk are sustainable.

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

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

Development should follow the standard FRA approach provided by the Environment Agency and CIRIA, as follows:

- Flood Risk Standing Advice for Local Planning Authorities. PPS25 (national) Version 2.0. (January 2009)
- CIRIA Report C624 “Development and Flood Risk – Guidance for the Construction Industry” (2004).

The general requirements of a FRA are listed in Appendix E of PPS25 and within the Practice Guide to PPS25. Further guidance on the level of detail required for a FRA can be found in the Environment Agency’s Flood Risk Assessment guidance notes available at http://www.environment-agency.gov.uk/research/planning/82587.aspx.

5.1.4 Guidance for Development within Each Flood Zone

A FRA should be commensurate with the risk of flooding to the proposed development. For example, where the risk of fluvial flooding of the site is negligible (Flood Zone 1 Low Probability) there is little benefit to be gained in assessing the potential risk to life and/or property as a result of this source of flooding. The particular requirements for FRAs within each of the Flood Zones delineated within PPS25 are outlined below. However PPS25 highlights that it is necessary to assess all sources of flood risk, such as surface water runoff when undertaking a FRA

For further details see http://www.environmentagency.gov.uk/researchplanning/93498.aspx.

Flood Zone 1 Low Probability

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

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

Flood Zone 2 Medium Probability

To satisfy the requirements of the Sequential Test, PPS25 recommends that development within Flood Zone 2 should be restricted to ‘essential infrastructure’, ‘water compatible’, ‘more vulnerable’ or ‘less vulnerable’ land uses (see Table 2.1) for a list of types of development appropriate for these land use classifications).

Where non-flood risk related planning matters dictate that highly vulnerable development should be considered further within Flood Zone 2 it will be necessary to carry out the Exception Test.

PPS25 states that for the Exception Test to be passed:

- It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared.
- 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
- A FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

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

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

Flood Zone 3a High Probability

To satisfy the requirements of the Sequential Test, PPS25 recommends that development within Flood Zone 3a should be restricted to 'Less Vulnerable' and 'Water Compatible' land uses (see Table 2.1 for a list of types of development appropriate for these land use classifications).

Where non-flood risk related planning matters dictate that 'More Vulnerable' development or 'Essential Infrastructure' should be considered further within Flood Zone 3a, it will be necessary to carry out the Exception Test (as discussed above).

An FRA should include the following:

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

Highly vulnerable development is not suitable in this Flood Zone.

Flood Zone 3b Functional Floodplain

PPS25 recommends that development within Flood Zone 3b should be restricted to 'water compatible' land uses (see Table 2.1 for a list of types of development appropriate for these land use classifications).

Where non-flood risk related planning matters dictate that 'Essential Infrastructure' should be considered further within Flood Zone 3b it will be necessary to carry out the Exception Test (see above for details).

In Flood Zone 3b, in accordance with Table D1 PPS25, any proposed development should be designed and constructed to:

- Remain operational and safe for users in times of flood;
- Result in no net loss of floodplain storage;
- Not impede water flows, and;
- Not increase flood risk elsewhere.

A FRA should include the following:

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

Highly vulnerable, more vulnerable and less vulnerable development is not suitable for this Flood Zone.

5.1.5 Additional Guidance

This section provides additional information for developers wishing to develop in areas of undefended and defended floodplain, as well as how to raise floor levels and provide compensatory storage where required in areas such as these.

Undefended Floodplain

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

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

Defended Floodplain

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

Residual risk from the breach or overtopping of defences needs to be considered as part of a FRA. Defra's Flood Risk Assessment Guidance for New Development (Ref: 29) and the supplementary note (Ref: 28) provide guidance on the level of risk related to distance and flood depth for overtopping and breaching scenarios.

The objectives of a breach analysis are as follows:

- To determine the Rapid Inundation Zone where there is a potential risk to life;
- To investigate the impact of the proposed development on the flood risk to others; and
- To test the effectiveness of mitigation measures.

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

Raised Floor Levels

It may be feasible to reduce the risk to a development through raising the ground level above the design flood level, as shown below in Figure 5.1.

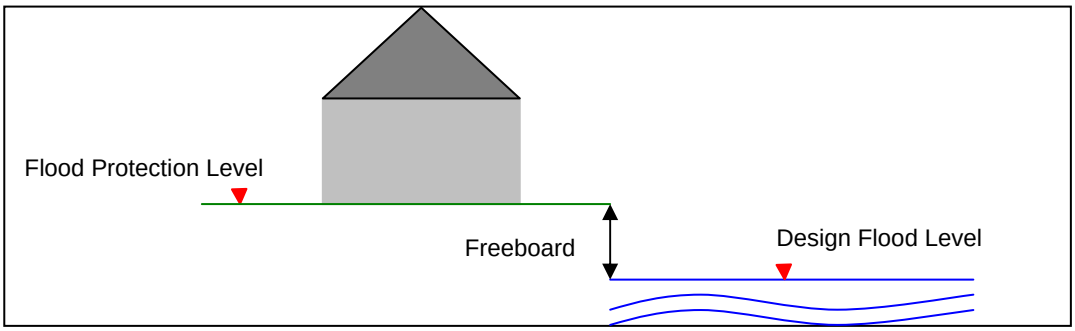

Figure 5.1 – Flood Protection Level

Floor levels should be raised above the 1% AEP fluvial flood level plus an allowance for climate change assuming a 20% increase in flow over the next 100 years. There is no need to allow for the 0.5% AEP coastal/tidal flood levels in the Bedford Borough as there is no risk of coastal/tidal flooding.

Floor levels will be subject to the approval of Bedford Borough and/or the Environment Agency/IDB.

Compensatory Storage

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

level. Further guidance on compensatory storage is available within 'Development and Flood Risk- Guidance for the Construction Industry', CIRIA 624 section A3.3.10.

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

5.1.6 Dry Islands

In some circumstances areas located within Flood Zone 1 can be surrounded by areas at a greater risk from flooding (i.e. Flood Zones 2 and 3). These areas located within Flood Zone1 are referred to as dry islands and even though the site may not be at risk from flooding, it can present a hazard to those located within these dry islands in times of flood as access routes may become impassable. If a development falls within a dry island or for more information on dry islands that it is recommended the interested party contacts their local Environment Agency Planning Liaison team on 08708 506 506.

5.1.7 Surface Water Drainage Assessment

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

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

- Assessment of whether the development will increase the overall discharge from the site by calculating the change in area covered by roofs and hard-standing;
- Details of how overland flow from the new development can be intercepted to prevent flooding of adjacent land;
- Details of how additional onsite surface water attenuation can be provided to mitigate against known flooding problems or as a result of incapacity on the drainage systems; and
- Demonstration that overland flows will not increase flood risk to both existing development and receiving watercourses.
- Calculations showing pre and post development impermeable areas, discharge rates and method of disposal including storage volumes where required. Agreement of these details should be sought from the Environment Agency/IDB and sewerage authorities.

Further guidance on Surface Water Drainage methodology, design and implementation is contained within Ref. 27 and 'The SuDs Manual' CIRIA 697, 2007.

Groundwater Consideration

Due to the high degree of variability when considering groundwater flooding, it is important to ensure that the potential risk of groundwater flooding to a property is considered within a local context. This is most appropriate at the development application stage (i.e. as part of the detailed FRA). As described in section 4.1.3, groundwater flood risk is considered typically low in a large proportion of Bedford Borough. The areas in which groundwater flood risk is considered higher is where there are river terrace deposits present in the river valley, as within these deposits high water tables can develop.

Typically, groundwater flooding will not preclude development unless there is a demonstrated history of relatively frequent and problematic flooding on site. Where a potential risk of groundwater flooding is identified it may be necessary to, for example, incorporate flood-proofing measures and/or the raising of entry thresholds to mitigate possible damages. The adopted design of the proposed development will need to ensure that it does not result in worsening of the

risk posed to adjoining properties through, for example, the displacement of available groundwater storage capacity as a result of basement construction. As groundwater flooding can last for extended periods (up to six months in some cases), access to at risk areas should be an important consideration, as should the maintenance of utility services, particularly foul water services.

Another consideration with respect to groundwater is the effectiveness (or otherwise) of SuDs. The design of proposed developments should carefully consider the impact that raised groundwater levels may have upon the operation of SuDs during periods of heavy rainfall. Infiltration techniques will be compromised in areas in which the water table is elevated or there is limited soil permeability. The feasibility can only clearly be determined by considering ground investigation works on site.

The Water Cycle Strategy (Ref: 4) provides guidance on the type of SuDs that are considered appropriate for each of the key centres based on the geological setting.

5.1.8 Selection of Appropriate Mitigation Measures

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

There are several sources of information on potential mitigation measures, which include:

- Flood Risk Assessment Guidance for New Development, Environment Agency R&D (FD2320);
- Development and Flood Risk – Guidance for the Construction Industry, CIRIA 624; and
- Improving the flood performance of new buildings: flood resilient construction. Communities and Local Government, June 2007.

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

1. Measures that reduce the physical hazard, e.g. through raised defences or flood storage
2. Measures that reduce the exposure to the hazard, e.g. raise properties above flood levels
3. Measures that reduce the vulnerability to the hazard e.g. Flood Warning or emergency planning.

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

Flood Defence Walls or Embankments

Flood defences, fully funded by the development can be constructed and maintained in perpetuity to protect a new development. However, PPS25 states that this should be avoided where possible so that residual risks are not created. Where developers propose the construction of flood defences to protect a new development it must be demonstrated that other options such as upstream storage and attenuation of flows would not be feasible. In addition the impact on the risk of flooding elsewhere with defences in place needs to be assessed and managed, for example, through the provision of compensatory storage as detailed in section 5.1.5. Residual risk of flooding with flood defences also needs to be assessed and managed. It must also be demonstrated, as outlined in PPS25, that the proposal is compatible with the long-term flood risk management plans such as the CFMP and IDB management. Therefore it should be noted that the construction of new defences to facilitate new development should only be undertaken in exceptional circumstances and alternative options should be considered in the first instance.

Flood Storage

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

Building Design

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

Guidance on flood resilience is contained within 'Improving the Flood Performance of New Buildings- Flood Resilient Construction' DGCL, May 2007 and a basic level of flood resistance and resilience can be achieved through good building practice and complying with Building Regulations (ODPM, 2000).

Flood Warning

The Environment Agency provides Flood Warnings to a number of existing properties at risk of flooding to enable owners to protect life and manage the effect of flooding of their property. Flood Warning should only be provided as a measure to manage residual risk and should not be used as the sole measure to offer protection to a development. Section 3.3.4 provides further details on flood warning within the Bedford Borough.

Access and Egress

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

Sustainable Drainage Systems

Suitable SuDs techniques will vary from site to site depending upon factors including characteristics of the site (e.g. geology, topography and hydro-geological); goals of the LPA and developer; requirements of the Environment Agency and IDB; and long term maintenance issues.

There are also a number of environmental aspects that need to be considered when proposing SuDs techniques which include pollution control, groundwater recharge, amenity/recreational facilities and maintaining or restoring the natural flow regimes of watercourses.

The WCS provides a high level indication of which possible SuDs can be implemented in development area and it provides a Developer Checklist of the requirement for developers. To avoid duplication the Developer Checklist is not repeated in this document, any interested party should view the WCS.

5.2 Sites Allocated and Permitted for Development

There are a number of sites already allocated for development within the Bedford Borough, however the Flood Zone in which the individual developments fall will affect the type of development permissible. Appendix A12 highlights the type of development suitable for each of the currently allocated areas. Note that within Appendix A12 a number of the maps do not show any areas currently allocated for development, thus does not show suitable development type. However this mapping has been included for completeness. The vast majority of these allocated areas are in Flood Zone 1 and as such there are no restrictions on development type based on flood risk grounds or in Flood Zone 2 when the only restriction is that the Exception Test is passed for Highly Vulnerable development (all other development types are permissible). There are a

number of allocated sites for development which have associated FRAs. These sites are identified on Appendix A2.

In addition to the development allocations that Bedford Borough Council has already committed to additional allocations will be made as part of the Bedford development framework. The focus for development will be the urban areas of Bedford and Kempston, but allocations may also be made in the Key Service Centres.

This section will provide some information on the location of the Key Service Centres and detail the causes for consideration, in terms of potential flood risks, that face developers wishing to develop in these areas.

In general, the Bedford Borough is not at risk from coastal or tidal flooding and therefore all site specific FRAs do not need to acknowledge this factor.

5.3 Key Service Centres

It is also important to note here that although the Key Service Centres have been assessed in terms of potential flood risks, the site specific FRAs will need to investigate all sources of flood risk.

There are eight Key Service Centres located within the Bedford Borough two of which (Stewartby and Wootton) are located within the Bedford Growth Area. The following information relates to the settlements themselves rather than the parish.

Sharnbrook

Sharnbrook is a village which is at risk of flooding from both the River Great Ouse and the Sharn Brook, and some of the area lies within the Environment Agency's Flood Warning area. If sites in this area were to be developed a site specific FRAs will be required and may be subject to Exception Testing. Modelling may be required to refine Flood Zones 2 and 3 which are based upon the Sharn Brook. There are existing hydraulic models which can be adapted and used to refine the Flood Zones, however they were not made available for this SFRA.

Harrold

A significant portion of the village of Harrold is at risk of flooding from both the River Great Ouse and smaller drains. There is the potential for flooding from surface water bodies in the area. Harrold lies within the Environment Agency's Flood Warning Area and those residents that are at risk of flooding from the River Great Ouse are warned of potential flooding.

If sites in this area were to be developed a site specific FRA will be required and may be subject to Exception Testing. Modelled outlines which refine the Flood Zones have been made available for this SFRA.

Bromham

Bromham lies on the banks of the River Great Ouse and also several other smaller watercourses. If sites in this area were to be developed further a site specific FRA will be required and may be subject to Exception Testing. Modelling may be required to refine Flood Zones 2 and 3 for the tributary to the River Great Ouse. There are existing hydraulic models of the River Great Ouse which has been re-run to refine the Flood Zones. The smaller watercourses will require models to be developed which will refine the flood risk in these areas.

Clapham

Clapham is a village that lies on the banks of the River Great Ouse, although only a small part of the village lies within Flood Zones 2 and 3. If development were to take place in Clapham it would need to be outside the floodplain, otherwise it would be subject to a site specific FRA and a potential Exception Test. As previously stated there is an existing hydraulic model of the River Great Ouse which has been re-run to refine the Flood Zones.

Wilstead

Wilstead is a village that lies to the south of Bedford and adjacent to the new Wixams development. Although Wilstead itself is not subject to flooding from any main watercourses, it does have a number of ordinary watercourses that cross it. The ordinary watercourses are the responsibility of the IDB and the IDB have advised that the area is vulnerable to flooding from these ordinary watercourses. There is also a flood storage reservoir which reduces the risks of flooding to the existing properties (although operational issues have arisen due to the presence of protected species). Should development be required in the village, the ordinary watercourses will need to be modelled. At present the only hydraulic models that the IDB hold are for the Elstow Brook, which was developed for the Wixams allocation. The hydraulic model outlines have been developed by Hannah Reed and Associates but were not available for this Level 2 SFRA.

Great Barford

The village of Great Barford lies on the banks of the River Great Ouse. Smaller ordinary watercourses have their confluence with the River Great Ouse at Great Barford, and the IDB have advised that the area is vulnerable to flooding from the smaller ordinary watercourses. There are also two flood storage reservoirs at Great Barford, which reduces the risks of flooding to existing properties. If further development were to be required in this area, the development would need to take place outside of Flood Zones 2 and 3 or they would be subject to a site specific FRA and potentially an Exception Test, depending on the type of development.

Stewartby

The majority of Stewartby lies within Flood Zone 1, however if a development proposal is larger than 1ha, the developer will be required to produce a FRA and an appropriate surface water assessment will be required. Also if development is proposed outside of the current settlement area, it may be within Flood Zones 2 and/or 3 and as such a site specific FRAs will be required.

Wootton

Wootton lies within Flood Zone 1 and is not at risk of fluvial flooding. Any development in this area will have to mitigate surface waters and minimise flood risks from pluvial events and if a development is larger than 1ha, the developer will be required to produce a FRA and an appropriate surface water assessment will be required. Also if development is proposed outside of the current settlement area, it may be within Flood Zones 2 and/or 3 and as such a site specific FRA will be required.

5.4 Flood Defence and Mitigation

5.4.1 Flood mitigation

The WCS provides a review of the flood mitigation proposals for the eight Key Service Centres a summary of which is provided in Table 5.1. Further details are provided within the WCS.

Service Centre	Flood mitigation proposals
Stewartby	Stewartby Lake is designated as an online flood balancing reservoir. The IDB will undertake water level management of the Lake as a strategic asset and a key flood risk mitigation measure.
Wootton	The land covered by this Key Service Centre is located within the IDB district and therefore all proposed methods of surface water disposal will need their full agreement.
Harrold	There are two lakes situated to the north and east of Harrold, however the existing and potential use of the lakes as flood infrastructure is unknown.
Sharnbrook	To the south of Sharnbrook are a series of gravel pits which are currently filled with water and classed as a natural nature reserve. There

Service Centre	Flood mitigation proposals
	is a possibility that these pits present an opportunity for strategic storm/flood water management.
Bromham	Not stated
Clapham	Not stated
Great Barford	The IDB strategically manage flood risk to the Key Service Centre using the two recently constructed upstream flood storage reservoirs. One of which is Great Barford Lake approximately 1.5km upstream from Great Barford.
Wilstead	The IDB operate a flood storage reservoir to the south of Wilstead to reduce flood risk to the village.

Table 5.1 – Summary of flood mitigation proposals in the Key Service Centres

5.4.2 Sustainable Drainage Systems

SuDs are proposed to reduce potential surface water flooding and the range of techniques used are introduced in the WCS. The Bromham and Southern Clapham areas of the Bedford Borough are located within the Outer Source Protection Zone, which defines vulnerability of underlying aquifers. This site designation as defined by the Environment Agency results in the restriction of infilitration SuDs techniques. Further details for the potential use of SuDs within each of the Key Service Centres as outlined within the WCS are given in Table 5.2. This information taken from the WCS focuses on the potential use of infiltrate SuDS within each of the Key Service Centres, However it is important to note that other forms of SuDS may be appropriate, which have not been included within Table 5.2 such as swales, attenuation ponds, green roofs, permeable paving and perforated pipes.

Service Centre	Comments on SuDs
Harrold	The nature of the geology underlying Harrold means that it is likely that infiltration SuDs are suitable at this location.
Sharnbrook	The geolgy underlying Sharnbrook would be favourable for the implemenation of infiltration SuDs at this location.
Clapham	Southern Clapham is located within an Outer Source Protection Zone as identified by the Environment Agency and as such the use of infiltration SuDs are likely to be restricted. In addition the geology in nothern Clapham is such that infiltration SuDs would not be suitable.
Bromham	Infiltration SuDs are suitable in south Bromham. Subject to confirmation of ground investigation infiltration SuDs may be suitable for north and west Bromham. The Environment Agency's designation of an Outer Source Protection Zone in east Bromham is likely to mean there are restrictions on the use of infiltration SuDs in this area.
Wootton	As identified in the WCS the geology underlying Wootton is such that neither infiltration nor soakaway SuDs are appropriate at this location.
Wilstead	With the exception of the area to the south of Wilstead the use of infiltration SuDs would not be appropriate. Ground investigations would be required prior to proposals of implementing infiltration SuDs.
Stewartby	As identified in the WCS the geology underlying Stewartby is such that neither infiltration nor soakaway SuDs are appropriate at this location.
Great Barford	There are locations where infiltration SuDs would and would not be appropriate for implementation in this area. Prior to suggestion of possible sites for this SuDs technique ground investigation would be

Service Centre	Comments on SuDs
	required.

Table 5.2 – Possibilities for SuDs at each of the Key Service Centres

The Defra 'Making Space for Water' (2004) (Ref: 9) publication advisies that a long term adoption strategy would be crutial to the success of effective and efficient SuDs management given that there is at present there is no standard framework for the adoption and maintanence of SuDs infrastructure. As a result of Recommendation 20 in the Pitt Review and the Flood and Water Management Act 2010 (Ref: 39) it is now the responsibility of County and Unitary Authorities to consent, adopt and maintain SuDs, as part of their overall resonsibility for local flood risk management.

As part of ongoing development within Bedford and the surrounding area, a strategic surface waters plan was published on behalf of the Marston Vale Surface Waters Group which follows PPG25 guidance. In the light of the new PPS25 guidance this plan is currently being reviewed. The plan seeks to promote a series of policies to encourage a sustainable and integrated approach to the major development that is proposed for the Marston Vale area. The Marston Vale Surface Waters Plan seeks to mitigate surface water in the following ways:

- By carrying out strategic watercourse improvements and/or providing balancing ponds to serve large areas (i.e. source control at strategic development size scale rather than individual property source control).
- The strategic SuDs should be adopted by public bodies, such as the Forest of Marston Vale becoming the landowner responsible for amenity and land management and the IDB adopting the asset and using its powers to manage and maintain the flood risk management elements.

Water storage and attenuation appears to be the primary focus for sustainable drainage in Bedford Borough.

The IDB have highlighted that there is a series of brick pits within the south of the Bedford Borough and it is the aspiration to use these brick pits for flood storage and recharge. These brick pits would then be linked using the Elstow Brook to provide additional amenity values.

Bedford Borough Council wishes to try and adopt a strategic approach to surface water mitigation. Similar to that of the Marston Vale Surface Waters Plan, it is hoped that the policy and guidance for the use of SuDs within the region will be adopted for the larger of the proposed developments.

The primary function of SuDs is for managing flood risk to protect people and property. Developers must ensure that the design of any surface water system considers future maintenance and operation in perpetuity of the development. For example, experience has shown that protected species can adopt SuDs facilities (such as balancing ponds) as habitat which compromises the performance of the system as maintenance can be restricted. Therefore careful consideration should be given at an early stage to the design and type of SuDs in context with other factors.

The Flood and Water Management Act (Ref: 39) provides further encouragement for the uptake of SuDs which includes presenting options for ownership and the new responsibility for adoption of these systems. The Act also enhancies the role of local authorities in coordinating a partnership approach for the implementation of SuDs as well as taking responsibily for consenting, adoption and maintenance. This new role for local authorites will aid the Government with the recommendations outlined in the Pitt Review to provide a more comprehensive approach to flood risk management. It is the production of SWMPs that aid with a strategic delievery of SuDs systems which can provide effective flood risk mitigation measures.

Recommendation 18 in the Pitt Review of the summer 2007 floods which suggests 'local surface water management plans as set out under PPS25 and co-ordinated by local authorities should provide the basis for managing all local flood risk'.

5.4.3 Surface Water Management Plans

The increasing pressure of development and the importance of flood risk consideration in the planning process in PPG25 (now superseded by PPS25) instigated the Marston Vale Surface Waters Group to commission Hannah Reed to complete the Marston Vale SWMP. The plan outlines policies for the Marston Vale district in terms of surface water management which supports Government objectives relating to flood risk and the environment.

The Flood and Water Management Act outlines the increased responsibility the Local Authorities have with regards to surface water management and the production of a SWMPs will become an increasingly important tool in this delivery. The use of SWMPs has also been promoted within PPS25.

Defra have produced a draft technical guidance document on the preparation of SWMPs (Ref: 5) that takes into account lessons learnt from the 15 Integrated Urban Drainage pilots. This guidance will aid in the delivery of SWMPs. Prior to the recent enactment of the Flood and Water Management Act the technical guidance on SWMPs was updated in March 2010. A factsheet has been produced as part of this Level 2 SFRA which is included within Appendix G that provides guidance on SWMPs and recommendations for a Bedford Borough SWMP. It is proposed that this current guidance will be updated, with a revised option available autumn/winter 2009 and as such SWMPs commissioned after this time should make use of the update version. The SWMP should also make use of the Environment Agency Areas Susceptible to Surface Water Flooding Mapping to determine key focus areas where further assessment of surface water flood risk should be carried out.

The Marston Vale SWMP provides information which can be developed for a Bedford Borough SWMP using current guidance. It can be summarised that the aim of the Bedford Borough SWMP would be to strategically manage surface water flooding through surface water attenuation and balancing ponds. This strategic approach can promote recreational facilities and other benefits as an additional product in comparison to dealing with surface water runoff on site specific basis for each development proposal.

It is recommended therefore that a Bedford Borough SWMP is commissioned which can build upon the Marston Vale SWMP. In order to bring this document inline with Government SWMP guidance the SWMP must include:

- Up to date policy guidance – the Future Water strategy and the Governments guidance on SWMPs;
- Policy context – PPS25, RSS14 and local development frameworks;
- Current development allocations as outlined in the Local Plan; and
- The latest flood risk information – SFRAs, WCS, CFMP and the latest hydraulic modelling for watercourses within the Bedford Borough

The production of the Bedford Borough SWMP would follow the outlined four stages, preparation, risk assessment, options and implementation and review as outlined in the Government Guidance (Ref: 5).

The importance of developing a SWMP for the Bedford Borough is further highlighted by the number of properties identified by the Environment Agency to be at risk from surface water flooding (almost 5,300 within the Bedford Borough).

5.4.4 Flood defence assets

The current CFMP outlines the policies for flood risk measures in the Bedford Borough. Where there is the potential to use areas as active floodplains, techniques will be implemented to increase flood attenuation at that location, with the aim that flood risk will decrease at downstream locations. This is discussed further in section 5.5.

Further details in relation to the CFMP policies for flood defence assets have not been outlined here. This is because the policies which are outlined within the current CFMP have the potential to be altered for the update CFMP which will be released in July 2010. This is to ensure that the best available data is being used to inform these polices because poor modelling lead to inadequate supporting evidence for the current policies. The revised CFMP should be adhered to once it has been delivered.

5.5 Potential Land Development

Windfall sites

The suitability of windfall sites should be considered at a strategic level. This would be achieved through a policy which identifies broad locations and quantities where according to the Sequential Test, the development is acceptable or not. This Level 2 SFRA can be used to determine where windfall sites can be appropriately located, in terms of flood risk. If the windfall site falls within Flood Zone 2 or 3, this SFRA will determine the type of development that will be suitable for the windfall site and whether further site specific FRAs will be required for the windfall site. For further details refer to the Determining the Flood Risk (PPS25) Sequential Test for Planning Applications document (Ref: 40).

Flood compensation areas

Areas suitable for floodplain compensation in context to allocated development sites should be included within the proposed Surface Water Management Plan and/or within any site specific FRA and thus to avoid repetition floodplain compensation areas have not been investigated for this Level 2 SFRA.

5.6 Limitations and Assumptions

The Level 2 SFRA makes use of the best available data at the time of writing which includes flood outlines. For the River Great Ouse and as such the main source of fluvial flood risk to the Bedford Borough the flood outlines provided have been produced from model re-runs only. The required output of this Level 2 SFRA also includes an indication of the Functional Floodplain and Flood Zone 3 with an allowance for climates change. In areas where these outlines were not available it was assumed that the functional floodplain would be represented by Flood Zone 3 and that Flood Zone 3 with an allowance for climate change would be represented by Flood Zone 2. This assumption was agreed with Bedford Borough in the meeting held on the 11th January 2008 (Ref: 37). The consequence of this assumption is that the functional floodplain is a conservative estimate of flooding at the 5% AEP and thus development restrictions imposed by this designation may be stricter than if the functional floodplain outlined was refined.

The hazard rating given to each of the Key Service Centres is based on the fluvial flood risk at the upstream extent of the watercourse located within the developed area. It is appreciated that this risk classification does not represent the hazard to the entre Key Service Centre, and thus a hazard rating has only been given for one spot location within the Key Service Centre. It is also important to note that this hazard rating can only be given to areas that are covered by hydraulic models which are available for this SFRA as the model has to be re-run to provide the necessary flood attributes (i.e. velocity, onset and depth). It is assumed that without the access to 2D modelling this method provides the most suitable indication of fluvial flood hazard.

6. Conclusions & Recommendations

6.1 Conclusions

There are a number of conclusions which can be made from this Level 2 SFRA, these are as follows:

1. The main source of flooding in the Bedford Borough is from fluvial sources, in particular the River Great Ouse, which poses a significant risk to a number of developments within the Bedford Borough.
2. At present there are no flood defences which have been identified to be in poor condition where urgent repair work is required. It is assumed that the Environment Agency will maintain the defences to a suitable standard.
3. On the most part the effect of climate change on the fluvial flood outlines is minimal, particularly in developed areas. The exception to this is the industrial area located between Elstow and Wilstead. However at this point the best available data to represent the 1% AEP event with an allowance for climate change was the 0.1% AEP outline provided by the Environment Agency. If additional modelling is carried out for this area it is possible that the flood outline for the climate change scenario will be refined.
4. Surface water flooding as identified in the DG5 register, provided by Anglian Water, indicates that there are two main areas at risk from this type of flooding within the Bedford Borough, Kempston and to the south east of Bedford Park.
5. Defra have also identified areas at risk from surface water flooding. Great Barford is the Key Service Centre most at risk with 470 properties at risk. The other Key Service Centres are at a lesser risk with five of the seven having more than 100 properties at risk. Sharnbrook and Stewartby with the least risk of surface water flooding.
6. Mapping showing areas that are susceptible to surface water flooding indicate that relatively large areas of the Bedford Borough are at risk from surface water flooding. All the Key Service centres have areas that are susceptible to surface water flooding, with Great Barford potentially the most affected.
7. This SFRA has been completed with the best available data at the time of writing and as data and policy is updated, revision of this SFRA would be required to keep the content current. This includes the update version of the Great Ouse CFMP which is due in 2010 and the Elstow Brook modelling which was not available at the time of writing.
8. The IDB and Level 1 SFRA identified that there may be a groundwater flood risk in Wilstead, Cotton End, Cardington and Kempston. Subsequence to further investigation it has been determined that Wilstead and Cotton End (and Keysoe where a possible groundwater flooding event occurred in 2000-2001) are underlain by Oxford Clay and Kellaways Beds, thus leading to a low flood risk within these areas. Kempston and Cardington are situated on terrace deposits which, due to their permeability, may result is a slightly high groundwater flood risk than elsewhere within the Bedford Borough, although this risk is not deemed to be significant.
9. It is likely that the most suitable approach to tackling surface water flooding in the Bedford Borough is to implement a strategic approach. As identified by the IDB the brick pits in the south of the Bedford Borough provide an opportunity for this. This information should be included in the production of a SWMP that provides the options for strategic surface water management.
10. The majority of areas allocated for development in Bedford Boroughs Local Plan are situated within Flood Zone 1 and as such development type is not restricted based on fluvial flood risk grounds. However there are a number of sites that have allocated areas located within

Flood Zone 2 and 3 and the Functional Floodplain, which mean there are restrictions on development type. The areas which are most restricted due to their location within the Flood Zones are the development to the east of Bromham; development in the Biddenham Loop (Kempston); the Wixams development site situated between Elstow and Wilstead; and the development in Great Barford. Site specific FRAs have been carried out, which have guided the location of built development within the sites identified within Bedford Boroughs Local Plan.

11. The Flood Risk Factsheets produced for each of the Key Service Centres have been produced to allow quick reference for developers and other interested parties for information on Flood Risk to the sites, potential mitigation, suitable SuDs and the types of development which are suitable.

6.2 Recommendations

There are a number of recommendations that can be made as a result of this Level 2 SFRA these are as follows:

1. To improve the understanding of flood risk in the Key Service Centres, more detailed analysis should be carried out. The Environment Agency have stated that 2D modelling and associated hazard outputs for the Flood Zones within the Bedford Borough will be completed by early 2011 and thus when these outputs are available the mapping provided in this SFRA may have to be revised.
2. According to routine inspection of the flood defence assets there are no structures which require immediate or urgent repairs or maintenance. It is therefore recommended that there should be a continuation of routine maintenance which is required to ensure the structures are kept up to the required standard.
3. It is recommended that a SWMP is completed for the Bedford Borough which should build upon the findings in the Marston Vale SWMP. It is the responsibility of Bedford Borough Council to coordinate the production of the SWMP in line with the Flood and Water Management Act. The SWMP should make use of the Environment Agency mapping, which identifies areas susceptible to surface water flooding, as a basis for locations where further assessment of surface water flood risk should be carried out.
4. Additional modelling is undertaken to distinguish between Flood Zones 3a (High Probability) and 3b (Functional Floodplain) such that identification of possible sites for floodplain restoration is more effective.
5. It is recommended that during the completion of site specific FRAs for development located within any of the Key Service Centres, the Flood Risk Overview factsheets given within Appendix G of this report are consulted as the first step in identifying possible flood risk on a site specific basis.
6. This Level 2 SFRA should be used to inform site specific FRAs, however it is recommended that in some cases the FRAs will need to create additional hydraulic models to determine flood risk at an individual site location.
7. This Level 2 SFRA provides the necessary information needed to apply the Sequential and Exception Tests to development proposals in the Bedford Borough and therefore should be used for these purposes in line with PPS25.
8. The Level 2 SFRA should be used to form part of the evidence base for the LDF, the Supplementary Planning Documentation, and decisions regarding land allocation and policies. The SFRA will be considered an integral part of the Sustainability Appraisal of relevant component documents of the LDF.
9. The policies outlined in the update CFMP, due for release in July 2010 should be adhered to.

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Appendix A – Mapping

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Appendix B – DG5 Register

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Appendix C – Asset Condition List

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Appendix D – Flood Onset Hydrographs

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Appendix E – Hazard Rating Classification

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Appendix F – Drainage Solutions at various Proposed Developments

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Appendix G – Factsheets

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