AECOM

North Kesteven Strategic Flood Risk Assessment
2008 Revision
Report

North Kesteven District Council
November 2009

Prepared by: ....
Roy Lobley
Associate Director

Checked by: ....
Barry Barton
Principal Engineer

Approved by: ....
Philip McLoughlin
Regional Director

North Kesteven Strategic Flood Risk Assessment (2008 Revision)

Rev No.	Comments	Checked by	Approved by	Date
A	Initial Draft	BB	PMcL	Nov.2008
B	Second Draft (Revised Brief)	BB	PMcL	Dec.2008
C	Third Draft	BB	PMcL	Jan.2009
D	Fourth (Reconfigured) Draft	RL	PMcL	April 2009
E	Fifth Draft			Sep.2009
F	Final Draft	BB	RL	Sep 2009
G	Final report issued to Client	BB	RL	Nov 2009

1 The Forum, Minerva Business Park, Lynch Wood, Peterborough, PE2 6FT
Telephone: 01733 391456 Fax: 01733 391139 Website: http://www.aecom.com

Job No 60046082 Reference Re01G Date Created November 2009

Table of Contents

- This page left blank intentionally -

Tables and Figures

LIST of TABLES

LIST of FIGURES

- This page left blank intentionally -

Executive Summary

Introduction

The original North Kesteven Strategic Flood Risk Assessment, (SFRA), was published in September 2002 and has subsequently been used to inform the Council's planning policies.

However, it only provided flood risk assessments of twenty-six separate potential development areas throughout North Kesteven rather than being a comprehensive strategic assessment of flood risk everywhere in the District.

North Kesteven District Council, (NKDC), has commissioned this revised and updated SFRA which will be used to inform the Core Strategy of the District Council's Local Development Framework, (LDF),

North Kesteven District is shown on Figure 1.1

The first part of the SFRA was an assessment and mapping of flood risk over the whole of North Kesteven in accordance with the Flood Zones, (FZ), in Planning Policy Statement 25 (PPS25).

The second part is a more detailed assessment of actual flood risk and the flood hazard where significant development might be expected or where flood risk is considered to be significant.

NKDC has defined two specific study areas which are shown on Figure 1.2.

Development Planning

The current Regional Spatial Strategy for the East Midlands (RSS8) was published in March 2009 as the East Midlands Regional Plan and it provides a broad development strategy for the East Midlands up to 2026. The plan has taken account of PPS3 and identifies the housing provision for each Housing Market Areas (HMA, together with the district based provisions.

The Council has drawn up two hierarchies of settlements, one for the Lincoln Policy Area and one for the remainder of the District, with four tiers of settlements in each hierarchy. This SFRA has considered the First and Second tier settlements as those most likely to be subject to further major development.

Level 1 Strategic Flood Risk Assessment

The SFRA is at the core of the PPS25 approach. It provides the essential information on flood risk, taking climate change into account that allows NKDC to understand the risk across its area so that the Sequential Test can be properly applied.

A level 1 SFRA will be sufficiently detailed to allow the application of the Sequential Test and to identify whether development can be allocated outside high and medium flood risk areas, based on all sources of flooding or whether the application of the Exception Test is necessary

PPS25 defines three distinct FZs which are based on the probability of river and sea flooding to which an area of land is currently subjected, ignoring the presence and effect of existing flood defences or other man-made obstructions to flood flows, These three FZs, are given for both fluvial and tidal flood risk in Annexe D to PPS25 (Table D1).

The Flood Zones are shown on Figures 3.1.

Sources of Flooding

North Kesteven covers a large and predominantly rural area situated on the western side of Lincolnshire, south of the City of Lincoln. The District straddles the Oolitic Limestone ridge (the Lincoln Edge) that runs from north to south up the western side of the county, roughly parallel with the larger chalk ridge to the east, the Lincolnshire Wolds. On either side of the limestone ridge are extensive areas of relatively level and low-lying land; the Vale of Trent to the west and the Lincoln Fens to the east.

The drainage pattern of North Kesteven, both west and east of the limestone ridge, is dominated by the River Witham. Although the great majority of the district lies within the Witham catchment the south eastern part of the district drains to the South Forty Foot Drain and a very small area on the western fringe of the district drains to the River Trent.

Each of the potential sources of flooding are described in Section 4 and Appendix A and their associated paragraph references are shown on Figures 3.1.

Flood Risk Management

Whilst the FZs ignore the presence of any formal defences there are a number of flood risk management measures in place in the district to reduce the level of flood risk. Section 5 of the main report looks at how the flood risk is being managed to begin to understand the actual level of risk to inform the sustainability appraisal, subsequent planning policies, the Exception Test and site specific planning applications

Climate Change

The fluvial flood envelopes which appear on the Environment Agency's FZs were produced on a national basis using the J-flow modelling software and a topographical model based on natural ground level contours that automatically ignore all man-made intrusions in the landscape such as flood defences. The FZs were produced from J-flow model runs using hydrological estimates of current 100-year and 1000-year return period flood flows as inputs to the model.

The impacts of climate change have the potential to increase the river flows for the 100 and 1000 year flood events which could increase these flood envelopes. There are no published FZs showing the potential extent of FZ 3 and 2 in the future. For this SFRA it has been agreed with the Environment Agency that, taking a precautionary approach, in order to indicate the potential effect of climate change on the extent of the FZs, the planning authority should use the present day FZ 2 envelope as an indication of the possible extent of FZ 3 in 100 years time given the current predictions for climate change. This potential FZ 3 is shown on Figure 6.1

Local Plan Environmental Objectives

Planning legislation requires that as part of the Local Development Framework preparation the Council is required to undertake a Sustainability Appraisal (SA) incorporating a Strategic Environmental Assessment (SEA) of potential future LDF local planning policies and Plans being developed. SA is a tool for assessing the impact of policies and proposals against a range of sustainability objectives so that decisions can be made that accord with the objectives of sustainable development.

The Council has a series of SA objectives. which are a key 'tool' to assess the sustainability of potential future local planning policies, including appraising potential options and alternatives considered in their preparation

This SFRA will help support the objectives, particularly in relation to climate change and reducing flood risk, by adopting the Sequential Test and Exception Test where required.

Sequential Test

PPS25 states that the risk-based Sequential Test should be applied at all stages of planning and the FZs are the starting point for the sequential approach. Where there are no reasonably available sites in FZ 1 decision makers allocating land in spatial plans should take into account the flood risk vulnerability of land uses and consider sites in FZ 2. Only where there are no sites available in FZs 1 and 2 should they consider the suitability of sites in FZ 3, applying the Exception Test if required.

Development Planning Sequential Test

North Kesteven District Council have drawn up two hierarchies of settlements, one for the Lincoln Policy Area and one for the remainder of the District, with four tiers of settlements in each hierarchy. This SFRA has considered the First and Second tier settlements as those most likely to be subject to further major development. and the Sequential Test has been applied to those locations.

Development Control Sequential Test

It is suggested that a Sequential Test search areas is used for certain types of planning applications.

Exception Test

PPS 25 states that the Exception Test should be applied, only after the Sequential Test, to Local Development Documents site allocations for development and used to draft criteria-based policies against which to consider planning applications.

For the Exception Test to be passed:

a) 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. If the Development Plan Document has reached the 'submission' stage the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal;

b) The development should be on developable, previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and

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

To inform the Exception Test it was necessary to undertake further, more detailed Level 2 SFRAs for Sleaford and the Lower Witham Fens. For the Western Growth Corridor in the parish of Skellingthorpe, which is outside of the existing built up area of the village, and North Hykeham a Level 2 SFRA has been included in the Lincoln Policy Area SFRA.

Level 2 Strategic Flood Risk Assessment

PPS25 states that where the level 1 SFRA demonstrates that land in FZ 1 cannot accommodate the necessary development then the Exception Test needs to be applied and a more detailed Level 2 SFRA will need to be carried out.

Areas within the High Probability Zone (FZ 3), on fluvial or tidal floodplains, may have a standard of protection, due to established flood defences or their location within the floodplain, which reduces their probability of flooding. This degree of flood risk to which these areas are subject may well be significantly less than that implied by their PPS25 FZ, provided that those defences are maintained at their current standard of protection.

The reduced probability of flooding, allowing for the defence, is called in this report "Actual Flood Risk"

Potential development areas in different parts of FZ 3 may be at different level of actual flood risks, particularly in an area with flood defences. However, whilst the probability of actual fluvial flooding may well be less than 1%, because of the defences, the area will still fall within FZ 3.

In order to apply the sequential approach to areas within the FZs the LPA will need to rank development according to actual flood risk This more detailed assessment of flood risk within specific study areas constitutes a Level 2 SFRA as described in PPS25.

Actual Flood Risk

In order to establish the actual level of flood risk it is necessary to understand how flooding is developed within the District, understand the history of flooding, and establish any affect man-made features can have on actual flood risk. The actual flood risk to the two study areas is described in Sections 14 and 15 of the main report.

Flood Hazard

In a major flood event, where a river is confined within flood defences there may be an appreciable difference between the water level on one side of the flood defence and the ground level in the defended area behind that defence. If that defence were then to fail, whether through the collapse of a floodwall or the breaching of an embankment, there would be a sudden inrush of flood water into the defended area. The velocity and depth of water cascading through the breach could, initially at least, be sufficiently great to sweep people off their feet resulting in their death by injury or drowning. The premature failure of a flood defence structure is by its nature a residual risk, but its potentially fatal consequences dictate that it be given equal consideration in flood risk assessment.

As flood water pours through a breach it will fan out across the hinterland behind the defences, and its velocity and depth will both decrease with distance from the breach..This will be determined by the flood level / ground level difference (head of water), the width of the breach, and the land surface topography behind the breach. PPS25 and its Practice Guide specify the determination of a Rapid Inundation Zone and also refer to Flood Risk in Assessment Guidance for New Development Phase 2 R & D Technical Report FD2320.

For this SFRA the three Flood Hazard zones as referred to in FD2320 will be used as follows:

- Danger for All
- Danger for Most
- Danger for Some

Study Areas

For this SFRA only Sleaford and the Lower Witham Fens have been subjected to a level 2 SFRA. The location of the two study areas is shown in Figure 1.2.

Flood risk sources considered in the Level 2 assessment include all open watercourses (rivers, streams, canals, arterial drains and riparian drains) and, where applicable, principal surface water and combined (foul + surface water) sewers.

Sleaford Town

The boundary of the study area is that of the Sleaford curtilage line shown on Inset Map No.52 in the North Kesteven Adopted Local Plan 2007. The irregularly shaped study area extends over about 560 hectares (compared with 1,838 ha for the whole of Sleaford parish) and measures approximately 3km from both north to south and from east to west. The general layout of the study area is shown in Figure 13.1.

The result of the hydraulic modelling indicates that flooding would not occur for the 100 or 200 year events. If any of the raised flood defences failed the only properties at risk of flooding would be houses at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated.

Lower Witham Fens

For the purposes of this study, the Lower Witham Fens study area has been defined as the extensive area of fenland between the Car Dyke and the River Witham or the South Forty Foot Drain (or to the District boundary where it lies to the west of these two watercourses), stretching from Washingborough in the north to the boundary with South Kesteven at Swaton in the south. The whole of the study area's western boundary is defined by the Car Dyke. Location plans of the study area are given in Figures 13.2.

Virtually the whole of the study area consists of pump-drained fenland, within either the Witham First Drainage District or the Black Sluice Drainage District. Within the study area the boundary between the two Drainage Districts lies between the Kyme Eau (River Slea) and Billinghay Skirth. For most of its length the eastern edge of the study area is bounded by the two high-level watercourses, the Witham and the South Forty Foot. Most of the land in the study area is below flood levels in those watercourses and is thus protected from them by raised earth embankments.

A number of smaller tributary watercourses run from west to east across the study area, conveying upland water under gravity from land west of the Car Dyke to the Witham or to the South Forty Foot Drain. Like the major watercourses into which they drain, these are all high-level watercourses confined between floodbanks. From north to south they are, in sequence, Sandhill Beck, the four Delphs, Billinghay Skirth, Kyme Eau, Heckington Eau (Head Dyke), Helpringham Eau, Helpringham South Beck and Swaton Eau along the study area's southern boundary. They are all Main Rivers and are shown in Figure 13.2.

With the exception of some 'islands' of higher ground on the western fringes of the study area, notably in the Billinghay and the North and South Kyme areas, the whole of the study area lies below the 5mOD contour. Within the study area fens, land levels are generally around 2m and 3mOD but with some land in South Kyme Fen as low as 1mOD.

These high-level watercourses effectively and conveniently divide the study area into a series of eleven 'flood compartments' separated from each other by the floodbanks which follow the high-level watercourses.

Most of the study area is sparsely populated, although it includes two small villages, North and South Kyme, and about half a dozen smaller settlements. Despite its extensive area, approximately 175 sq.km, the total population of the study area is not more than 2,000.

The flood hazard zones for the Lower Witham Fens study area are shown on Figures 15.1.

Sequential Approach

A sequential risk-based approach to determining the suitability of land for development in flood risk areas is central to the policy statement of PPS 25 and should be applied at all levels of the planning process.

Sequential Test

The level 1 SFRA has enabled the study to apply the Sequential Test to First and Second Tier settlements as identified in the NKDC Local Plan, which are the most likely to be subject to further housing allocations.

The Sequential Test has indicated the possibility of further development in areas of FZ 3 and 2 and in order to apply the Exception Test a more detailed level 2 SFRA has been undertaken.

Exception Test

This detailed SFRA has defined the actual flood risk within the FZs and, if development is identified, this will also enable the sequential approach to be applied to those areas.

Sleaford

Significant parts of the Sleaford study area are shown to be in FZ 1, i.e. little or no flood risk and these areas should be developed in preference to other, higher flood risk areas. However, Sleaford is likely to be the focus for significant growth in the future.

Further development should take place in FZ 1 and, where there is no available land in FZ 1, development should then be directed to FZ 2. Only where this is not possible should development be considered in FZ 3, and where necessary the Exception Test will need to be applied.

The detailed assessment of actual flood risk has indicated that these areas are protected from flooding for events <1% and, if no alternative sites in FZ 1 are available, then this area is at low risk of flooding and could be made available for further development.

Although sites may have a standard of protection from flooding of <1% they may still be subject to flooding from a failure or overtopping of the defences. However, for Sleaford it has been found that there is an insignificant risk from breaching of the defences and therefore this is not considered to be an issue.

Lower Witham Fens

For the Lower Witham Fens it is unlikely that any major development will take place in this area but it is still necessary to apply the sequential approach to individual planning applications, so that development takes place in the lowest flood risk areas and is made safe, particularly as in this area a failure of the raised defences could be dangerous

Within FZ 3 and 2 the actual level of flood risk varies and it is possible to apply a sequential approach to land allocation and for planning applications in this study area where land at the least risk of actual flooding should be developed in preference to higher flood risk areas.

Any new development should be avoided in the flood hazard zone of “Danger to All” and should only be allowed in “Danger to Most” if suitable mitigation measures can be designed as part of a detailed site specific flood risk assessment.

Guidance For Planners and Developers

The section provides guidance to planners and developers on how to manage flood risk through the design of the development.

Where design solutions are considered appropriate, they need to meet the policy objectives of PPS25 that it must be safe without increasing flood risk elsewhere and where possible reduce flood risk overall.

A range of measures can be used to manage flood risk at development sites. NKDC will use the information in this SFRA to establish the design criteria developers will need to meet through LDD policy.

Developers should discuss proposals at the earliest possible stage with the LPA, Environment Agency and other key stakeholders so that design issues can be agreed and innovative design solutions considered if necessary.

Sustainable Drainage Systems

Traditional drainage is designed to move rainwater as rapidly as possible from the point at which it has fallen to a discharge point, either a watercourse or soakaway, however this approach has a number of harmful effects.

North Kesteven District Council expect planning applications, whether outline or detailed, to demonstrate how a more sustainable approach to drainage is to be incorporated into development proposals, and for detailed design information to be submitted at the appropriate stage and may use planning conditions to secure the implementation of SUDS.

North Kesteven area is underlain by mudstone (west of Lincoln) and clay (east of Lincoln), with a ridge of limestone running north-south through Lincoln. The mudstone and clay areas are not very permeable, and as a result cannot store large quantities of water and are not suited to the infiltration methods.

Conclusions

The study has applied the Sequential Test to the First and Second Tier settlements in the NKDC Local Plan by using the Environment Agency FZs. As there is sufficient land in FZ 1 for future development the majority of new development should take place in FZ 1.

For this SFRA Sleaford and the Lower Witham Fens have been subjected to a Level 2 SFRA.

For land currently shown to be within FZ 2, NKDC should consider this to be within FZ 3 in 100 years time and may require further detailed consideration of the impact of climate change.

For Sleaford whilst parts of the study area are shown to be in FZ 2 and 3 the defences that exist reduce the risk of flooding to less than 1%. Failure of the raised defences would only affect properties at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated.

Significant parts of the Sleaford study area are shown to be in FZ 1, and these areas should be developed in preference to other, higher flood risk areas. The detailed assessment of actual flood risk has indicated that these areas are protected from flooding for events <1% and, if no alternative sites in FZ 1 are available, then this area is at low risk of flooding and could be made available for further development.

Most of the Lower Witham Fens is shown to be within FZ 3 with defences reducing the probability of flooding, however failure of these defence could result in loss of life. For the areas of the Lower Witham fens within FZ 3 and 2 the actual level of flood risk varies and development should take place in the lowest flood risk areas and made safe.

The flood hazard zones show that for a distance of some hundred meters from the raised defences a breach would prove dangerous to all and any further development in this area should be avoided. A large portion of the Fen is shown to have a danger to most rating and any development in this area would need to be informed by a detailed flood risk assessment identifying how the development could be made safe.

Where design solutions are considered appropriate, they need to meet the policy objectives of PPS25 that it must be safe without increasing flood risk elsewhere and where possible reduce flood risk overall. Planning applications must demonstrate how a more sustainable approach to drainage is to be incorporated into development proposals.

Recommendations

It is recommended that North Kesteven District Council:

- Use this Strategic Flood Risk Assessment to inform the Core Strategy of the District Council's Local Development Framework.
- Continue to apply the Sequential Test using the Environment Agency FZs
- Undertake further supporting studies as necessary based on the information on the Environment Agency Areas Susceptible to Surface Water Flooding maps.
- Consider adopting a precautionary approach when looking for further development sites and consider the effect of climate change on the extent of FZs.
- Within Sleaford ensure that further development takes place in FZ 1 and only be allowed in FZ 3 following the successful application of the Exception Test.
- Note that the detailed assessment of actual flood risk has indicated that Sleaford is protected from flooding for events <1% and it has been found that there is an insignificant risk from breaching of the defences in Sleaford.
- Within the Lower Witham Fens discourage any development in the "Danger for All" flood hazard rating.
- Within the Lower Witham Fens ensure that any development in the "Danger to Most" flood hazard rating is informed by a detailed flood risk assessment identifying how the development could be made safe
- Require a FRA for all planning applications in accordance with PPS25 and the Practise Guide
- Will establish the design criteria developers will need to meet through LDD policy.
- Encourage developers to discuss proposals at the earliest possible stage with the Council, the Environment Agency and other key stakeholders.
- Use planning conditions to secure the implementation of SUDS
- Use recommended draft policies in their LDDs

- This page left blank intentionally -

1 Introduction

1.1 Bullen Consultants Limited (subsequently merged with Faber Maunsell and now known as AECOM) were commissioned by North Kesteven District Council (NKDC) in December 2001 to undertake a Strategic Flood Risk Assessment (SFRA) of North Kesteven.

1.2 North Kesteven District is shown on Figure 1.1.

1.3 Planning Policy Guidance Note 25 (PPG25), which had been issued in July 2001 by the Department for Transport, Local Government and the Regions, expected local planning authorities to apply a risk-based approach to the preparation of their development plans in respect of possible flooding. Appendix F of PPG25 contained specific guidance for planning authorities and those working on their behalf on the methodology to be used in undertaking a flood risk assessment.

1.4 In December 2006 PPG25 was superseded by the Department for Communities and Local Government's Planning Policy Statement 25 (PPS25), supplemented by a Practice Guide.

1.5 The original North Kesteven SFRA Report was published in September 2002 and has subsequently been used to inform the Council's planning policies. However, the original SFRA only provided flood risk assessments of twenty-six separate potential development areas ("allocated sites") nominated by the Council throughout North Kesteven rather than being a comprehensive strategic assessment of flood risk everywhere in the District.

1.6 In 2002 two-dimensional (2D) hydraulic modelling techniques for the analysis of the extent and impact of flooding from breaches in raised flood defences were still in their developmental stage. However, since the publication of the original North Kesteven SFRA Report 2D modelling techniques have become more generally available and are now routinely employed, where applicable, in strategic flood risk assessments. Because of these advances in hydraulic modelling techniques the Environment Agency were keen to see the North Kesteven SFRA revised using a 2D modelling methodology to provide a comprehensive assessment of the impact of flood defence breach scenarios at key locations in the District.

1.7 Two dimensional breach scenario modelling requires a precise ground surface model of the land at risk of flooding from a breach in a flood defence line. Whereas in 2002 there had been no detailed high-definition topographic map coverage of the District available, the Agency's national programme of aerial light detection and radar (LiDAR) surveys has since been extended to include most of North Kesteven, making the use of 2D breach scenario modelling feasible.

1.8 The Environment Agency therefore entered into discussions with NKDC and agreement was reached on the need for a revised and updated SFRA which would be used to inform the Core Strategy of the District Council's Local Development Framework. Work on the Core Strategy had started in autumn 2007.

1.9 NKDC requires a Level 1 SFRA for the whole of North Kesteven supplemented by a Level 2 SFRA for two study areas.

1.10 The key Level 1 outputs from the project can be summarised as follows:

- Strategic Flood Risk Maps of North Kesteven showing the current extent of flood risk across the District, the functional floodplain and main rivers.
- An assessment of the implications of climate change predictions on flood risk at allocated development sites.
- The identification of areas at risk of flooding from sources other than rivers.
- The location of any flood risk management measures, including flood warning systems.
- The identification of locations where future development could significantly increase flood risk elsewhere.
- Guidance for developers on the preparation of Flood Risk Assessments and the applicability of different Sustainable Urban Drainage Systems (SUDS) techniques at key development sites.

1.11 The second component is the more detailed level 2 assessment of actual flood risk and the flood hazard in two areas of the District where significant development might be expected or where flood risk was considered to be significant. The District Council nominated and defined two study areas, one comprising the town of Sleaford and the other the extensive area of fenland along the eastern edge of the District. A map showing the location and extent of these two study areas (referred to in this Report as Sleaford Town and Lower Witham Fens respectively) is presented in Figure 1.2.

1.12 In addition the Tier 1 and 2 settlements identified in the Local Plan have been considered and where necessary further Level 2 assessments have been recommended.

1.13 The Lincoln Policy Area is centred on the City of Lincoln but takes in the contiguous parts of the neighbouring Districts, including the northern edge of North Kesteven. An SFRA had been prepared for the Lincoln Policy Area in 2004 under PPG25 and is currently being revised in accordance with PPS25. Taking into account the concurrent preparation of the Lincoln Policy Area SFRA and the inclusion of part of North Kesteven within the Policy Area, NKDC requested liaison with those undertaking the Lincoln Policy Area SFRA to avoid any discrepancies in flood risk envelopes in the area of overlap between the two SFRAs.

1.14 The 2002 North Kesteven SFRA and the Environment Agency's latest Flood Zones (FZs) (see Section 3) have been used as the starting point for this study. These have been supplemented by other information supplied by the District Council, the Environment Agency, Anglian Water Services, Internal Drainage Boards and other sources. Due consideration has also been given to the requirements for the preparation of SFRAs given in PPS25 and its associated Practice Guide, as well as the Environment Agency's guidance notes on flood risk assessment issued to Local Planning Authorities (LPAs).

1.15 The methodologies used to carry out the revision and updating of the SFRA and the more detailed flood risk assessments for the two study areas, together with the results obtained, are described in the following sections and the results are also presented in the following maps:

- Environment Agency FZs covering the whole District,
- Potential effect of climate change on FZ 3
- Hazard Zone maps for Lower Witham Fens study area.

1.16 This Report supersedes the 2002 SFRA Report.

1.17 This document has been prepared by AECOM for the sole use of the client, North Kesteven District Council (“the Client”) as a revision and updating of the Council’s Strategic Flood Risk Assessment and as a flood risk assessment of two study areas in North Kesteven for the Council, in accordance with generally accepted consultancy principles, the budget for fees, and the terms of reference agreed between AECOM and the Council. Any information provided by third parties and referred to herein has not been checked or verified by AECOM unless otherwise expressly stated in the Report. No third party may rely upon this document without the prior and express written agreement of AECOM.

2 Development Planning

East Midlands Regional Spatial Strategy

2.1 The current Regional Spatial Strategy for the East Midlands (RSS8) was published in March 2009 as the East Midlands Regional Plan and it provides a broad development strategy for the East Midlands up to 2026. The plan has taken account of PPS3 and identifies the housing provision for each Housing Market Area (HMA) together with the district based provisions.

2.2 Policy 13a in the Regional Plan allocates provision of new housing between individual Local Planning Authority areas for the period between 2006 and 2026. North Kesteven is part of the Central Lincolnshire HMA as shown in Table 2.1 below.

Central Lincolnshire HMA	Annual Apportionment From 2006	Total Housing Provision 2006-2026
Lincoln Principal Urban Area	990	19,800
North Kesteven	**560**	**11,200**
West Lindsey	480	9,600
Total	**2,030**	**40,6000**

Table 2.1 - Future Housing Provision in the Central Lincolnshire HMA

2.3 The northern half of North Kesteven (including North Hykeham, Skellingthorpe, Waddington, Washingborough, Heighington and Metheringham) is included within the Lincoln Principal Urban Area. The above figures for North Kesteven do not include contributions from those parts of the Lincoln PUA that lie in the district.

North Kesteven Adopted Local Plan

2.4 The Council adopted the Local Plan in September 2007 and it is intended that the policies will be saved for three years. In Section 2 of the Plan, Objectives, Strategy, Monitoring and Review, the Council has drawn up two hierarchies of settlements, one for the Lincoln Policy Area and one for the remainder of the District, with four tiers of settlements in each hierarchy. This SFRA will consider the First and Second tier settlements as those most likely to be subject to further major development.

2.5 The council has also started on the preparation of the Local Development Framework (LDF) especially the core strategy, and one of the key pieces of evidences will be this SFRA, which will help inform the future scale and location of the development in order to deliver the District housing allocations contained in the Regional Plan.

- This page left blank intentionally -

3 Level 1 SFRA - Introduction

Planning Policy Statement 25

3.1 The SFRA is at the core of the PPS25 approach. It provides the essential information on flood risk, taking climate change into account that allows NKDC to understand the risk across its area so that the Sequential Test can be properly applied.

Sequential Test

3.2 A level 1 SFRA should be sufficiently detailed to allow the application of the Sequential Test and to identify whether development can be allocated outside high and medium flood risk areas, based on all sources of flooding, or whether the application of the Exception Test is necessary

Flood Zones

3.3 PPS25 defines three distinct FZs based on the probability of river and sea flooding to which an area of land is currently subjected, ignoring the presence and effect of existing flood defences or other man-made obstructions to flood flows, These three FZs, are given for both fluvial and tidal flood risk in Annexe D to PPS25 (Table D1) and are summarised in Table 3.1 below :-

Zone	Characteristic	Assigned Annual Probability of Flooding
1	Low Probability	Fluvial & Tidal Less than 0.1% (1 in 1000 or more years)
2	Medium Probability	Fluvial 0.1% to 1% (from 1 in 100 to 1 in 1000 years) Tidal 0.1% to 0.5% (from 1 in 200 to 1 in 1000 years)
3a	High Probability	Fluvial Greater than 1% (1 in 100 or less years) Tidal Greater than 0.5% (1 in 200 or less years)
3b	Functional Floodplain	Fluvial & Tidal Greater than 5% (1 in 20 or less years)

Table 3.1 - PPS25 Flood Risk Zones

3.4 Following a comprehensive tidal and fluvial flood risk mapping exercise carried out across the country, the Environment Agency issued a set of FZs to each LPA in England and Wales during Summer 2004.

3.5 The FZs were prepared using nationally consistent methodologies for the determination of FZs. For fluvial flooding the FZs were derived by using a broad scale model called J-Flow, which estimated the flow in a watercourse that would arise from 1:100 and 1:1000 year flood events, and calculated how much water would be contained within the natural channel and how far the remainder would propagate across the floodplain. The FZs exclude the effect of existing flood defences, and the effects of de-facto defences such as road and railway embankments, major artificial drainage channels etc. These FZs therefore show the probability of flooding which, in areas where defences exist, may be significantly greater than the actual risk of flooding.

3.6 The FZs are not limited to Main Rivers but include all watercourses with a catchment area of more than 3 sq.km.

3.7 The FZs are shown on Figure 3.1.

Functional Floodplains and Washlands

3.8 In PPS25, where they form the basis for FZ 3b, Functional Floodplains are defined as "land where water has to flow or be stored in times of flood". PPS25 goes on to state that "SFRAs should identify this FZ (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes.)".

3.9 Land "where water has to flow or be stored in times of flood" is commonly known as washland. For the purpose of this study Functional Floodplains have therefore been taken to be any area of land in the District used as washland or within which the actual annual probability of flooding equals or exceeds 5%, or at least once in 20 years.

3.10 The Environment Agency operates two principal washlands in North Kesteven. The first of these is Branston Island, an area of land enclosed between the River Witham and the loop of the Old River Witham. Although Branston Island lies to the east of the River Witham it is actually within North Kesteven. The second is the River Witham Controlled Washland situated at the confluence of the Rivers Witham and Brant, 7km upstream of the Brayford Pool in Lincoln. Both these washlands and their operation are described in detail in Section 5. As far as we are aware the Agency has not formally designated any other areas of floodplain in the District associated with Main Rivers as 'functional'.

4 Sources of Flooding in North Kesteven

Introduction to the North Kesteven District

4.1 North Kesteven covers a large and predominantly rural area situated on the western side of Lincolnshire, south of the City of Lincoln. The District straddles the Oolitic Limestone ridge (the Lincoln Edge) that runs from north to south up the western side of the county, roughly parallel with the larger chalk ridge to the east, the Lincolnshire Wolds. On either side of the limestone ridge are extensive areas of relatively level and low-lying land; the Vale of Trent to the west and the Lincoln Fens to the east.

4.2 The drainage pattern of North Kesteven, both west and east of the limestone ridge, is dominated by the River Witham. Although the great majority of the district lies within the Witham catchment the south eastern part of the district drains to the South Forty Foot Drain and a very small area on the western fringe of the district drains to the River Trent.

Major Sources of Flooding

4.3 Initially flood risk is assessed based on the Environment Agency's FZs described in Section 3 which discounts the presence of defences. Each of the potential sources of flooding within North Kesteven is described in the following paragraphs and their associated paragraph references are shown on Figures 3.1.

Tidal Flooding

4.4 Tidal flooding occurs when an exceptionally high tide, almost always accompanied by a storm tide surge, overtops and/or breaches the tidal defences along a coastline or tidal estuary. Although North Kesteven does not lie along a coastline or does not have a tidal river flowing through the District, a small area around North Scarle falls within the River Trent's tidal floodplain.

4.5 A tributary of the River Trent, The Mill Dam Dyke, is a significant tidal flood risk source. The Mill Dam Dyke (or Girton Fleet downstream of Baxter Bridge) flows through the village of North Scarle and discharges into the River Trent via a modern tidal outfall sluice. The watercourse can become tidelocked impacting on water levels within the channel.

4.6 Another potential tidal influence within North Kesteven is determined by the ability of the River Witham to discharge via its tidal outfall at Boston (Grand Sluice). The River Witham's discharge can be restricted for significant periods of time when there is a high tide which has implications for fluvial flood risk as far upstream as North Kesteven.

Fluvial Flooding

4.7 Fluvial flooding can occur as a result of the overflowing or breaching of river or stream banks when the flow in the watercourse exceeds the capacity of the river channel to accommodate that flow. The major watercourses which are considered to present a significant fluvial flood risk within North Kesteven are:

- Upper River Witham (upstream of Lincoln, including R.Brant)
- Lower River Witham (downstream of Lincoln, including the embanked 'Delphs')
- Billinghay Skirth and tributaries
- Car Dyke system
- South Forty Foot Drain (including its embanked tributaries)
- River Slea / Kyme Eau
- Fossdyke Canal

4.8 These watercourses are described briefly below, but for further detail refer to Appendix A.

Upper River Witham and River Brant

4.9 The Upper River Witham rises south of Grantham and enters North Kesteven near Beckingham. It then continues northwards through the Trent plain towards Lincoln via Stapleford and Bassingham, leaving the District at North Hykeham.

4.10 The River Brant rises in South Kesteven between Marston and Claypole and flowing north, parallel with the Upper Witham, enters North Kesteven near Stragglethorpe. It then continues north along the eastern edge of the Trent plain joining the Witham about 2.5km downstream of Aubourn.

4.11 See Figure 3.1 (Sheets1, 3, and 5)

Lower River Witham

4.12 The Lower River Witham emerges from the eastern end of Brayford Pool in Lincoln, flows through the centre of Lincoln and eastwards towards Bardney. From Bardney the River Witham flows south-east towards Chapel Hill, where it leaves the District, to its tidal limit at Grand Sluice, Boston.

4.13 A flood relief channel, the Sincil Dyke (or South Delph as it is known to the east of the Lincoln), leaves the Upper Witham at Boultham, 1.8km upstream of Lincoln city centre, and follows a parallel but lower-level course through the city to the east and south of the River Witham, rejoining the River Witham about 1km upstream of Bardney. The relief channel helps to reduce river levels through Lincoln.

4.14 Downstream of Lincoln a series of four high-level embanked channels - the Branston, Nocton, Metheringham and Timberland Delphs - run from west to east across the Lower Witham fens connecting the Car Dyke (see below) with the Lower Witham. These Delphs are all Main Rivers but carry relatively modest flows.

4.15 Apart from the Delphs, the only right bank tributary of the River Witham of any consequence between Lincoln and Billinghay Skirth (see below) is the Heighington Beck. This spring-fed limestone stream with a 26 sq.km catchment would originally have been intercepted by the Car Dyke (see below) but it now discharges to the South Delph along Sandhill Beck, a short length of embanked channel across the narrow strip of fen north of Washingborough.

4.16 See Figure 3.1 (Sheets 2 and 4).

Billinghay Skirth

4.17 Scopwick Beck and Springwell Brook which drain the dip slope west of Billinghay converge just west of Billinghay to form the Billinghay Skirth. From Billinghay the Skirth flows eastwards through the main body of the River Witham Fens entering the River Witham, via pointing doors, just upstream of Tattershall Bridge.

4.18 See Figure 3.1 (Sheet 4 and 6).

Car Dyke System

4.19 The Car Dyke operates as a catchwater drain between Washingborough and Billinghay. North of Billinghay the Car Dyke intercepts the various minor spring-fed streams that drain the dip slope of the Lincoln Edge. The fenland between the Car Dyke and the River Witham is intersected by a series of elevated drainage channels known as the Delphs and flows in the Car Dyke are discharged under gravity into the heads of these Delphs. At Billinghay the Car Dyke discharges to Billinghay Skirth through a small sluice.

4.20 See Figure 3.1 (Sheets 2, 4 and 6).

South Forty Foot Drain

4.21 The South Forty Foot Drain is an artificial fen drainage channel which runs northwards and then eastwards in an arc from Guthram Gowt, near Bourne, for a distance of 33km to its outfall into Boston Haven, at Black Sluice in Boston. The South Forty Foot Drain forms the eastern boundary of North Kesteven for about 6.5km between Donington High Bridge and Swineshead,

4.22 See Figure 3.1 (Sheets 4, 6, 7 and 8).

River Slea / Kyme Eau

4.23 The River Slea rises near Ancaster, just beyond the western boundary of North Kesteven. Groundwater from large limestone springs just upstream of Sleaford is a major component of the flow in the river through the town. Below Sleaford the river has been diverted into the channel of what was once the Sleaford Canal, leaving its original course, now known as the Old River Slea, as a local low-level drainage channel to the south of the canal route between Sleaford and Anwick. At Cobblers Lock, downstream of Anwick, the two channels recombine and flow into the River Witham at Chapel Hill.

4.24 See Figure 3.1 (Sheets 5, 6 & 7).

Fossdyke Canal

4.25 The Fossdyke Canal connects the River Trent at Torksey to the River Witham at the Brayford Pool in Lincoln. A 4km length of the Fossdyke Canal northeast of Skellingthorpe forms the northern boundary of North Kesteven. The Skellingthorpe Main Drain, an arterial drainage channel, lies between the canal and the village and tends to intercept flood flows from the canal and divert them eastwards towards Lincoln.

4.26 See Figure 3.1 (Sheet 1).

Internal Drainage Board Arterial Drains

4.27 Internal Drainage Boards mainly operate in the lower parts of the country where the drainage is often pumped into the higher level main rivers. Land in pump-drained catchments is subject to two main but distinct types of flood risk. The first and more serious is inundation resulting from the overtopping or breaching of the flood defences of the high-level embanked watercourse into which the catchments are pumped. The second is flooding which can arise if the runoff entering the arterial drainage system exceeds the capacity of the pumps or that of the drainage channels leading to the pumping station. Residual risk flooding could also occur as a result of a mechanical or electrical failure at the pumping station.

4.28 There are four Internal Drainage Districts (IDBs) which lie partly or wholly within North Kesteven. These are:

- Black Sluice
- Witham First
- Upper Witham
- Newark Area

4.29 These IDBs maintain their drains for a standard of flood protection between a 1 in 10 year and a 1 in 75 year standard.

4.30 For more information on each of the IDBs see Appendix C and their respective websites.

Minor Sources of Flooding

4.31 In addition to the major sources of flooding outlined above, there are a number of other potential sources of flooding which although relatively minor, must nevertheless be considered in their potential strategic context. These various minor flood risk sources are considered in the following paragraphs.

Critical Ordinary Watercourses

4.32 Urban watercourses considered to be particularly at risk from blockages were designated 'Critical Ordinary Watercourses' (COWs) although this designation did not have any statutory status. COWs were designated in their respective areas by Local Authorities and Internal Drainage Boards, as well as by the Environment Agency. The Environment Agency has subsequently been adopting all COWs as Main Rivers, for which the Agency is responsible. Where a COW was separated from the previous Main River system by a length of non-Main River the intervening watercourse has also been classified as Main River.

4.33 In some areas COWs were designated by Internal Drainage Boards. No watercourses in the Black Sluice IDB's area designated as COWs have been adopted as Main River by the Environment Agency. The Witham First District IDB has not designated any watercourses in its area as COWs. The Upper Witham IDB has not designated any of its watercourses in North Kesteven as COWs. Mill Dam Dyke had been designated a COW by the Newark Area IDB and was adopted as a Main River by the Agency in 2006 for a distance of 3.7km from the Trent to Clog Bridge, just upstream of North Scarle.

4.34 Although COWs no longer exist as such, they are still of considerable interest as they indicate watercourses which have at some time been considered by a responsible statutory authority to present potential problems with flooding or impaired drainage capability. In 2007 the Environment Agency commissioned a detailed study of all COWs that had been en-mained in the Anglian Region. Only one of the nineteen ex-COWs listed in this study was in North Kesteven - Ruskington Beck.

4.35 The en-mained (COW) section of Ruskington Beck extended for 3.29km from the previous head of Main River through the centre of Ruskington to a point near Westfield House on the western edge of the village. The study confirmed that properties within the village in High Street and Manor Street were at the greatest risk of flooding, with a standard of protection (onset of flooding) of as little as 1 in 10 years in places. The study concluded that some sections of the Beck through the village had a high vulnerability to flooding and should be a priority for future assessment. It also concluded that for the sub reach along Manor Street the standard of flood initiation suggests that there is an appropriate standard of protection.

4.36 Although one of them was not included in the Agency's 2007 Report, the Agency's current large scale Main River map shows two ex-COWs in North Kesteven, Ruskington Beck and Skellingthorpe Beck. The latter is the 1,100m downstream section of a tributary of the Boultham Catchwater Drain which flows north through the centre of the village of Skellingthorpe from a point on the SW edge of the built-up area.

Groundwater Flooding

4.37 Groundwater flooding is often very different to flooding from rivers. It is generally not closely linked to recent rainfall amounts and it is difficult to predict its spatial extent. Groundwater flooding can often be of a much longer duration than fluvial flooding, lasting for several weeks, with significant social disruption. It is also harder to predict, so flood warning may not be provided.

4.38 Groundwater flooding occurs when the water table rises above the ground level and flows or ponds on the ground surface. Long term high rainfall totals are the primary cause of high groundwater levels, which means groundwater flooding is more likely during the winter months when we receive the majority of rainfall. The flooding archive only contains one groundwater flooding incident, the February 1997 flood in Sleaford when 200 acres and one property were flooded. However, the flood archive tends to focus on fluvial events and is not considered to be comprehensive, so this figure should be used with caution since there could be many more instances of groundwater flooding that have gone unrecorded. Groundwater flooding in Heighington has been identified. Unfortunately no detailed information is available for these incidents. The number of incidents however, suggests that groundwater flooding is not a significant issue in the District.

Surface Water Flooding

4.39 Surface water flooding happens when excess rainwater runs off across the surface of the land, rather than overflowing from a watercourse. It can be difficult to identify as it may be linked to fluvial flooding, groundwater flooding or sewer flooding. It can also occur on agricultural land, which means it is not recorded. Surface water flooding is likely to be of short duration and shallow depth, unless combined with fluvial, groundwater or tidal flooding or tidelocking.

4.40 The main mechanisms of surface water flooding are considered to be:

- Runoff during intense storms (e.g. summer thunderstorms) leading to the build-up of surface water. Properties at the foot of steep slopes may be particularly vulnerable. Urban areas are particularly susceptible to this type of flooding due to the high proportion of impermeable surfaces (e.g. roads, roofs) and the limited capacity of storm water drainage systems. This means that drains can often back up and watercourses may rapidly fill up and flood.
- Blockage of surface water drainage systems or drainage ditches during periods of high rainfall. This causes drains to backup and spill out elsewhere.
- High rainfall/local groundwater levels leading to the ponding of water in low-lying areas. This type of flooding can often occur seasonally to agricultural land. In fenland areas the pumped drainage system is designed to remove this excess water, but in particularly wet periods it may not be able to cope, leading to waterlogging or surface water flooding.

4.41 Surface water flooding is highly localised and widely distributed. It can cause regular and serious flooding locally, but there is little information recorded on previous flood events.

Areas Susceptible to Surface Water Flooding

4.42 The Pitt Review of the summer 2007 flooding emergency recommended that the Environment Agency, supported by local authorities and water companies should urgently identify the areas that are at highest risk from surface water flooding.

4.43 In July 2009 the Environment Agency issued a series of maps available to local authorities as the first deliverable from the national project set up to respond to this recommendation.

4.44 The Environment Agency defines surface water flooding as follows; "A surface water flood event that results from rainfall generated overland flow before the runoff enters any watercourse or sewer. Usually associated with high intensity rainfall (typically >30mm/hr) resulting in overland flow and ponding in depressions in the topography, but can also occur with lower intensity rainfall or melting snow where the ground is saturated, frozen, developed or otherwise has low permeability. Urban underground sewerage/drainage systems and surface watercourses may be completely overwhelmed, preventing drainage. Surface water flooding does not include sewer surcharge in isolation." This means surface water flooding can occur almost anywhere when it rains hard enough for the local topography and circumstances to be unable to absorb the rainfall.

4.45 The map has been produced using a simplified method that excludes underground sewerage and drainage systems, and smaller over ground drainage systems, excludes buildings, and uses a single rainfall event – therefore it only provides a general indication of areas which may be more likely to suffer from surface water flooding. The map provides three bandings, indicating 'less' to 'more' susceptible to surface water flooding.

4.46 The maps will provide general information on surface water flooding at this level and can be used for:

- Assessing the suitability of the map as an indicator for surface water flooding for your area before you make decisions based upon it;
- Informing SFRAs.

4.47 The maps must not be used :-

- For the sole evidence for any specific planning decision at any scale without further supporting studies or evidence;
- For the identification of individual properties susceptible to surface water flooding;
- Alone to show expected areas of surface water flooding;
- To interpret the maps as defining the flood extent for a specific probability;
- For consulting on applications with the Environment Agency;
- To incorporate into fluvial or tidal flooding maps in SFRAs, keep them separate;
- With a more detailed base map scale than 1:50,000. For example, do not use it with a 1:10,000 scale base map. But you can use it with 1:250,000.

4.48 The Environment Agency suggest that the use of the maps in planning will be to highlight areas where more detailed study of surface water flooding may be appropriate within SFRA. They are not appropriate to act as the sole evidence for any specific planning decision at any scale without further supporting studies or evidence. The maps have only recently been issues to the LPAs and have not been assessed as part of this SFRA.

Sewer Flooding

4.49 Flooding from urban sewer systems depends on a number of factors, such as network capacity, system blockages and water levels at their outlets.

4.50 In urban areas, surface water (rainwater) and foul sewage were historically drained by a single sewer pipe. This is known as a combined sewer. However more recent developments have installed separate foul and surface water systems. Combined sewers generally have insufficient capacity to convey all flows during a significant flood event. During such times, excess flows are discharged into adjacent drainage systems, usually a watercourse, via combined sewer overflows. When operating correctly, the discharge from combined sewer overflows is usually highly diluted due to the large volume of surface water present in the effluent. During large flood events, excess flood water can flood out of the combined sewer system at manholes and flood adjacent roads and houses and the risk of sewer flooding is generally restricted to urban areas.

4.51 Anglian Water Services provided a schedule of information on recent sewer flooding incidents in North Kesteven. These incidents were all attributed to overloading. Anglian Water consider a sewer to be overloaded when the flow during a storm is unable to pass through it due to a chronic problem such as a flat gradient and/or small diameter. Incidents resulting from temporary problems such as blockages, collapses, siltation and equipment failure are excluded. Anglian Water's schedule listed flooding incident locations by parish and postcode but did not give dates of incidents and, with one exception, did not distinguish between foul sewage and surface water flooding, although the schedule distinguished between internal and external flooding of properties. The information in the schedule is summarised in Table 4.1 on the next page.

STW Catchment	Parish	Postcode	Location
Anwick	Ruskington	NG34 9ER	Manor Street
	Ruskington	NG34 9TN	Walnut Close
Billinghay	Billinghay	LN4 4AY	Skirth Road
	Walcott	LN4 3SZ	The Drift / East View Jn.
Canwick	Bracebridge Heath	LN4 2LZ	Canwick Avenue
		LN4 2PH	Grange Road
	Branston & Mere	LN4 1UY	Cherry Avenue
	Washingborough	LN4 1AE	Fen Road
		LN4 1DZ	Keeble Drive
		LN4 1AT	Main Road
Helpringham	Helpringham	NG34 0RP	Vicarage Lane
Leadenham	Leadenham	n/k	n/k
Leasingham	Leasingham	NG34 8LT	Washdyke Lane
Metheringham	Dunston	LN4 2HB	Fen Lane
	Metheringham	LN4 2DZ	n/k (Incorrect postcode)
North Hykeham	North Hykeham	LN6 8JJ	Beverley Grove
		LN6 9AL	Station Rd / Leys Cl
		LN6 9RF	Delph Road
	Waddington	LN5 9AN	Brant Rd (Internal)
Osbournby	Osbournby	NG34 0DH	The Drove / New St Jn
Rowston	Scopwick	LN4 3NW	Main Street (2no)
Skellingthorpe	Skellingthorpe	LN6 5TX	Ferry Ln / High St Jn
		LN6 5SP	Gardenfield
		LN6 5SJ	Waterloo Ln
		LN6 9RH	Russell Ave
Sleaford	Sleaford	NG34 7RP	South Gate
		NG34 7PE	Sandhurst Crescent
		NG34 8TU	Summerfield Court
		NG34 7AS	The Drove
Washingborough	Heighington	LN4 1JS	High Street
	Potterhanworth	LN4 2DU	Barff Road

Table 4.1 Sewer Flooding Incident Locations in North Kesteven

4.52 Table 4.1 omits the single flooding incident (at Ruskington) specifically identified as caused by foul sewage. Of the total of 55 other incidents listed in the Anglian Water schedule, 42 were classified as “external” and 12 as “internal”. It is not known whether an “external” and an “internal” incident recorded at the same location represented the same incident.

Waddington Low Fields

4.53 At Waddington Low Fields, on the southern edge of Lincoln, there is an extensive area of recent residential development along the eastern side of Brant Road. This area is situated at the foot of the Lincoln Edge and has a lengthy record of drainage problems, including flooding of some houses, caused by runoff from the scarp slope above Brant Road.

4.54 Section 5 has details of the improvement scheme implemented to reduce this flood risk.

River Witham Catchment Flood Management Plan

4.55 The Environment Agency has prepared Catchment Flood Management Plans (CFMPs) for the whole of England and is preparing them for Wales. These documents present catchment-based policies for the future management of flood risk throughout that catchment over the next hundred years. The River Witham CFMP final report was completed in December 2008 as will be published later this year

4.56 The River Witham starts south of Grantham and flows northwards, through Lincoln, before turning south-east and discharging into the Haven at Boston and eventually the Wash. The CFMP area is predominantly rural with the main urban areas being Lincoln and Boston. The majority of the urban drainage within the CFMP area is managed by Anglian Water with five Internal Drainage Boards maintaining non main rivers and the Environment Agency being responsible for sea defenses and works on main rivers.

Current Flood Risk

4.57 The CFMP states that significant flooding problems are associated with the River Witham, its tributaries and the sea. The report identifies Lincoln and Horncastle at being particular risk from river flooding from the Witham. The flood risk identified in the CFMP take flood defences into account, unlike the Flood Maps available on the Environment Agency's website that do not take flood defences into account.

Future Flood Risk

4.58 The CFMP reports that climate change will cause the biggest increase in flood risk in the future in the River Witham CFMP area, through a combination of higher peak river flows and more extreme sea levels.

CFMP Flood Risk Management Policies

4.59 The River Witham CFMP area is divided into fourteen policy units, seven of which fall largely or partly within North Kesteven. Each unit represents similar types of flood risk, in terms of mechanisms of flooding, the level of flood risk etc. Each of the units has been assigned an appropriate flood risk management policy.

4.60 There are six pre-defined policies which the Environment Agency can choose from to apply to different parts of the CFMP area. These are:

CFMP Policy 1 **No active intervention** (including flood warning and maintenance). Continue to monitor and advise.

This policy may be selected for natural catchments where the river is connected to its floodplains and flooding has positive effects (e.g. it is beneficial for natural habitats). It may be applied where it has been recognised that the harm posed by flooding is not high, nor will it be in the future. In these instances costly interventions to manage low risks would not be appropriate.

CFMP Policy 2 **Reduce existing flood risk management actions** (accepting that flood risk will increase over time).

This policy may be selected for places where current and future risks do not warrant as much intervention (e.g. routine maintenance) as there is at present and it is clearly not worth continuing. Here the risk of flooding will be allowed to increase naturally over time.

CFMP Policy 3 **Continue with existing or alternative actions to manage flood risk at the current level** (accepting that flood risk will increase over time from this baseline).

This policy may be selected where the risks are currently managed appropriately and where the risk of flooding is not expected to increase significantly in the long term.

CFMP Policy 4 **Take further action to sustain the current level of flood risk into the future** (responding to the potential increases in risk from urban development, land use change and climate change).

This policy may be selected in places where the risk is currently managed appropriately, but flood risk is expected to rise significantly in the long term. In these circumstances, more would need to be done in the future to reduce the increase in risks.

CFMP Policy 5 **Take further action to reduce flood risk** (now and/or in the future).

This policy may be selected in places where the existing or future flood risk is too high. Action will need to be taken in the short and long term to reduce this level of risk, now and/or in the future.

CFMP Policy 6 **Take action with others to store water or manage runoff in locations that provide overall flood risk reduction or environmental benefits, benefits locally or elsewhere in the catchment.**

This policy may be selected in places, either local to a flooding problem or some distance away where flooding is not a problem. However, the principle behind this policy is that flood risk is transferred to places where flooding can bring benefits, which reduce the risk in areas where it is a problem. This may mean that floodplains can be restored and habitats improved, reducing the negative impacts of flooding elsewhere within the catchment. This may also include changing the way the land is used to hold water for longer within that part of the catchment, reducing flood risk elsewhere.

4.61 The seven policy units and their assigned policy are:

Policy Unit 1 - Upper Witham

4.62 The Upper Witham policy unit within North Kesteven extends northwards along the Witham Valley (Trent plain) from the District's southern boundary as far as the Witham (Lincoln FAS) Washland. The largely agricultural area includes a number of relatively small villages and a generally scattered population.

4.63 The CFMP considers that the risk of flooding within the policy unit is low and the risk to people and property will not increase significantly in the future. Consequently flood risk **Policy 2** to reduce current levels of flood risk management is proposed for this policy unit.

Policy Unit 3 - Lincoln

4.64 The Lincoln policy unit consists primarily of the City of Lincoln but also includes a number of the large surrounding suburban villages in North Kesteven, such as North Hykeham, Skellingthorpe and Waddington. The River Witham flows through the Lincoln Gap in the centre of the policy unit.

4.65 As this is a heavily and fairly densely populated urban area the CFMP proposes the adoption of **Policy 4** to take further action to sustain flood risk now and/or in the future.

Policy Unit 4 - Limestone Ridge

4.66 The Limestone Ridge policy unit within North Kesteven comprises the Lincolnshire Limestone outcrop stretching north from the Ancaster Gap to the southern outskirts of Lincoln. This policy unit is bounded by the Upper Witham policy unit on the west and The Fens policy unit on the east. There is a line of villages along the crest of the ridge and another line of villages along the spring line at the base of the dip slope, close to the western edge of the policy unit.

4.67 The limestone and its overlying soil are highly permeable and flood risk in the policy unit is considered to be minimal.

4.68 The Environment Agency does not undertake any flood risk management activities in this policy unit and the CFMP states that there is currently no flood risk in the policy unit. The CFMP therefore proposes the adoption of **Policy 1** that no active intervention for this policy unit.

Policy Unit 8 - The Fens

4.69 The Fens policy unit includes all of the Lower Witham Fens study area as well as the isolated pocket of fens west of Billinghay and, the dip slope of the Lincolnshire Limestone ridge north and south of Sleaford. Sleaford itself is excluded from this policy unit. Within North Kesteven much of this policy unit is defended by raised flood defence embankments.

4.70 The Witham CFMP states that there is currently a relatively low risk of flooding within The Fens policy unit, although this statement may reflect the sparsely populated nature of the defended fenland rather than the significant probability of its flooding at present.

4.71 The CFMP recommends for this policy area the adoption of **Policy 4** to take further action to sustain flood risk now and/or in the future.

Policy Unit 9 - Sleaford & Ancaster

4.72 This policy unit includes the valley of the River Slea from Ancaster downstream to Sleaford, the town itself and a handful of small villages.

4.73 The CFMP states that the urban area of Sleaford is not at risk of fluvial flooding and that there is therefore no risk to people, property or the local economy, although it considers that the villages of Ancaster and Wilsford are at risk of flooding from the headwaters of the River Slea.

4.74 The Witham CFMP recommends the adoption of **Policy 3** to continue with existing or alternative actions to manage flood risk at the current level for the Sleaford & Ancaster policy area.

Policy Unit 12 - Outer Lincoln North

4.75 This policy unit is located to the north west of Lincoln comprising the lower extent of the River Till and the majority of the Fossdyke Canal, including the River Till Washland. The south east corner of the policy unit is located within the District.

4.76 The CFMP states that there is currently a low level of risk within this policy unit but climate change will significantly increase the flood risk to Lincoln, the downstream policy unit.

4.77 The CFMP recommends the adoption of **Policy 6** to take action with others to store water or manage runoff in locations that provide overall flood risk reduction or environmental benefits, locally or elsewhere in the catchment and adopting the above policy will allow the flood risk in Lincoln to be sustained.

Policy Unit 13 - Outer Lincoln South

4.78 This policy unit is situated in the west of the CFMP area and extends from Claypole to the edge of Lincoln, including the River Witham and Brant Washlands.

4.79 The CFMP states that there is currently a low level of risk within this policy unit but climate change will significantly increase the flood risk to Lincoln, the downstream policy unit.

4.80 The CFMP recommends the adoption of **Policy 6** to take action with others to store water or manage runoff in locations that provide overall flood risk reduction or environmental benefits, locally or elsewhere in the catchment and adopting the above policy will allow the flood risk in Lincoln to be sustained.

5 Flood Risk Management

5.1 Whilst the FZs ignore the presence of any formal defences there are a number of flood risk management measures in place in the district to reduce the level of flood risk. Having considered the sources of flooding in the previous chapter we will now look at how the flood risk is being managed to begin to understand the actual level of risk to inform the sustainability appraisal, subsequent planning policies and the Exception Test.

Inappropriate Development in the Floodplain

5.2 One of the most effective ways to reduce flood risk is to limit the amount of development in the floodplain, thereby reducing the consequences of flooding. This is through the planning process and the SFRA and LDFs are an important vehicle to help achieve this. Where development is required, because of other sustainable reasons, it may be necessary to reduce the probability of flooding, and the consequences of flooding, through other measures.

5.3 The following paragraphs identify what measures are currently in place to reduce the flood risk to the existing developments in the District.

Flood Storage Areas

5.4 The principal source of flood risk in North Kesteven is the River Witham. At the time the original SFRA Report was published in 2002, nearly all the flood alleviation schemes described below were already in place, the exception being the Lower Witham Scheme. Improvements to Grand Sluice and Fiskerton Sluice circa 1980 have also contributed to the reduction of flood risk in the Lower Witham.

<u>Upstream of Lincoln – the Lincoln Flood Alleviation Scheme</u>

5.5 The Lincoln Flood Alleviation Scheme (FAS) was constructed in the late 1980s specifically to provide flood alleviation for the more low-lying parts of the city of Lincoln which, despite the presence of the Sincil Dyke, had been subject to occasional flooding from the River Witham. The scheme was designed to give a 1 in 100-year standard of protection to areas in Lincoln previously at risk of more frequent flooding and involved the construction of two off-line flood storage reservoirs created by constructing low earth embankments across the valleys of the Rivers Witham and Till upstream of Lincoln.

5.6 One of the two reservoirs is located at Aubourn, about 7km upstream of Lincoln, at the confluence of the Upper Witham and the River Brant where both rivers flow in embanked channels. When flood flows in the Witham reach a predetermined level a control sluice across the river downstream of the confluence is operated, diverting flood water from the river into the flood storage reservoir through two pairs of inlet/outlet sluices set in the river bank, one in the left bank of the Witham just upstream of the control sluice and the other in the left bank of the Brant upstream of Blackmoor Bridge. When the flood peak has passed, water is released from the reservoir back into the river. The maximum storage capacity of this reservoir is 6.3 million cu.m.

5.7 The second of the two flood storage reservoirs is located on the right bank of the River Till near Saxilby, about a kilometre upstream of the confluence of the Till and the Fossdyke Canal, where the River Till flows in an embanked channel. The mode of operation of this reservoir is virtually identical to that of the other reservoir on the Upper Witham, except that there is only one inlet/outlet sluice in the river bank. The maximum storage capacity of this reservoir is 3.2 million cu.m.

5.8 Although the primary function of the Lincoln FAS is to reduce flood risk in Lincoln, the retention of a large volume of flood water upstream of Lincoln will inevitably have some beneficial effect on flood risk along the Lower Witham as far downstream as Boston.

Downstream of Lincoln – Branston Island

5.9 Branston Island is the 87 hectare 'island' of farmland north of Bardney Lock enclosed between the loop of the old channel of the River Witham and its high level navigation channel above Bardney Lock. Since both channels are embanked watercourses which entirely surround it, the 'island' is at considerable risk of flooding. For this reason Branston Island has for many years been used as a flood storage reservoir.

5.10 When water levels in the Lower Witham reach a critical level, Branston Island Sluice, situated in the right bank of the Old River Witham 260m north of Bardney Lock, is opened and flood water from the river is allowed to inundate the island. The sluice remains open to allow the flood water to re-enter the river as water levels fall. Any water still remaining on the 'island' after the flood event has passed is released back to the river through a small low-level sluice or pumped to the river using portable pumping equipment.

5.11 At present the Branston Island inlet sluice gates are manually operated but the Environment Agency is investigating the provision of a mains electricity supply to the site so that the sluice gates can be electrically operated and remotely controlled.

5.12 The controlled flooding of Branston Island is intended to reduce fluvial flood peaks on the Lower Witham and thereby reduce flood risk as far downstream as Boston. However, the timing of the opening of the Branston Island sluices and the flooding of the island is critical, and is complicated by the cyclical tidelocking of the Lower Witham at Grand Sluice.

Downstream of Lincoln – the Lower Witham Flood Alleviation Scheme

5.13 As a result of a strategy study undertaken in the 1990s, a scheme was implemented to raise all the floodbanks along the Lower Witham to give a minimum defence standard of the 1 in 10 year flood level, plus freeboard, everywhere along the river. Improvement works have been carried out over a total length of approximately 30km of riverbank. It should of course be emphasised that in many places the defence standard exceeds this standard by a considerable margin.

5.14 The majority of the 54 locations where the defence standard has been raised to the minimum level are at the upstream end of the Lower Witham in North Kesteven, between Dogdyke and Washingborough. It had originally been proposed to provide formal overspill sections with locally reduced crest levels at selected locations along the west bank of the river so that controlled flooding would occur in predetermined flood compartments, but implementation of this work has been deferred on economic grounds until further studies have been undertaken.

5.15 Even without the provision of formal overspill sections, the limited 1 in 10 year defence standard of the floodbanks along the Lower Witham upstream of Kirkstead means that overtopping of these embankments and flooding of the adjacent fenland will always occur first, before any flooding elsewhere along the Lower Witham. This provides a substantial degree of flood risk attenuation downstream of North Kesteven where the defence standard provided by the river's floodbanks is considerably higher than that further upstream within the more sparsely populated fenland in North Kesteven.

River Trent

5.16 In the great flood of 1795 flood water flowing eastwards from the Trent reached the city of Lincoln. The flood water penetrated through the gaps in the low ridge that runs up the east side of the river from Collingham to Torksey. The most notable of these gaps are at North Scarle and Torksey (the Fossdyke Canal). In recent years the various gaps have been more effectively 'plugged' by the construction of substantial earth embankments along the west side of the A1133 (Newark to Torksey) road.

5.17 Only the gap through the ridge at North Scarle is of any immediate concern in this study. This gap has been ‘plugged’ by a flood bank erected along the A1133 road from Baxter Bridge to near Spalford. This embankment has a crest level of about 8.85mOD and is designed, with freeboard, to contain a 75 year return period flood in the Trent. (At overtopping the effective defence standard increases to 1 in 100 years.) The secondary tidal sluice across the Mill Dam Dyke just upstream of Baxter Bridge is associated with this defence line.

5.18 The Environment Agency states that the primary defence line which follows closely the right bank of the Trent in the North Scarle area has a crest level of about 7.24mOD and provides a 1 in 3 year defence standard for the land between the primary (riverside) and secondary (principal) defence lines.

Raised Defences

Flood Defence Condition Rating

5.19 The majority of the Main Rivers in this area have raised earth embankments or concrete floodwalls to reduce the probability of flooding. Without these defences adjoining land would be at risk of flooding at frequent intervals and the Environment Agency have permissive powers to provide, maintain and improve these defences.

5.20 The Agency’s Main River flood defences are subject to inspection at regular intervals. During an inspection the physical condition of each component of a defence line is assessed and a condition grade from 1 to 5 is ascribed to that component. These components include not only flood defence embankments and floodwalls but also sluices, weirs, culverts etc or any structure whose failure could jeopardise the physical integrity or derogate the standard of protection provided by the defence line.

5.21 Descriptions of each component of all Main River flood defences and the results of these inspections (i.e. the condition rating) are stored on the Agency’s National Fluvial and Coastal Defence Database (NFCDD). The five condition rating grades used in the NFCDD are defined in Table 5.1 below.

Condition Grade	Condition Rating	Description
1	Very Good	Cosmetic defects that will have no effect on performance.
2	Good	Minor defects that will not reduce the overall performance of the asset.
3	Fair	Defects that could reduce the performance of the asset.
4	Poor	Defects that would significantly reduce the performance of the asset. Further investigation needed.
5	Very Poor	Severe defects resulting in complete performance failure.

Table 5.1 - Environment Agency NFCDD Flood Defence Condition Rating

5.22 Condition ratings from the NFCDD for all the raised flood defences along Main Rivers in North Kesteven were supplied by the Environment Agency. This information was used to derive Figure 5.1 which illustrates the variation of flood defence condition ratings across the District. The Brief requires a review of the condition of raised flood defences in North Kesteven and this is given in the following paragraphs. To avoid excessive repetition it is assumed that all the Agency’s flood defences fall within either Grade 2 (Good) or Grade 3 (Fair) except where specifically mentioned, and only defences in Grades 1, 4 and 5 are identified specifically.

Upper Witham System (including R.Brant)

5.23 This group includes all raised defences upstream of the Lincoln City boundary. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 59%

Condition Rating 3 (Fair) 39%

5.24 Apart from a notable concentration of Condition 2 defences in the Witham Washlands area, Condition 2 and 3 defences are equally distributed elsewhere in the group. There are 1% of defences in Conditions 1 (Very Good) and 1% in Condition 4 (Poor). The latter are all located towards the head of the Boultham Catchwater Drain within the village of Skellingthorpe.

Fossdyke Canal

5.25 This group consists of the raised defences on the right bank of the Fossdyke along the North Kesteven boundary. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 96%

Condition Rating 3 (Fair) 4%

5.26 It is notable that the condition of the canal's right bank defences along the district boundary is consistently better than those along the left bank. The short section of right bank defences in Condition 3 are situated immediately downstream of the Lincoln Western Bypass (A46).

Lower Witham System

5.27 This group includes all raised defences along the right bank of the Lower Witham downstream of the Lincoln City boundary, including the South Delph and the Old River Witham. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 60% Condition Rating 3 (Fair) 39%

5.28 The Condition 2 defences are concentrated generally in the Bardney Island, Bardney, Kirkstead and Dogdyke areas. and in the Witham Washlands area, Condition 2 and 3 defences are equally distributed elsewhere in the group. The 1% of defences in Condition 4 (Poor) are all along Sand Syke, a minor flood risk source in the Washingborough area.

Car Dyke and The Delphs

5.29 The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 16%

Condition Rating 3 (Fair) 84%

5.30 These figures are somewhat misleading as they include the Condition 2 defences along the Metheringham Delph and the right bank of the Branston Delph - neither watercourse is now used to convey flood water. Nevertheless the preponderance of Condition 2 defences in this group should be noted. There are two small lengths, less than 1% in total, of Condition 4 (Poor) defences along the Car Dyke.

Billinghay Skirth System

5.31 This group includes the Billinghay Skirth from North Kyme to the Witham and the network of small embanked watercourses in the isolated fen area west of Billinghay / North Kyme. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 36%

Condition Rating 3 (Fair) 63%

5.32 Apart from Dorrington Dike's Condition 2 defences, most of the other flood defences in the group, including much of Billinghay Skirth itself, are in Condition 3. The defences of a small watercourse in Ruskington Fen (< 1% of the total) are in Condition 4 (Poor).

River Slea System

5.33 This group includes the canalised River Slea and Old River Slea between Sleaford and Cobblers Lock (Anwick), the Kyme Eau downstream of Cobblers Lock, and the Slea and Nine Foot River upstream from Sleaford. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 48%

Condition Rating 3 (Fair) 52%

5.34 The Old River Slea's defences downstream of Sleaford Bypass (A17) are entirely Condition 2 (Good). In Sleaford town the defences are largely Condition 3, with a short length (<1%) of Condition 4 defences in the town centre. Elsewhere, including the heavily embanked Kyme Eau, there is a slight preponderance of Condition 3 defences.

South Forty Foot Drain System

5.35 This group comprises the South Forty Foot Drain and all its Main River tributaries in North Kesteven, including the Head Dyke and Heckington Eau. The proportions of Condition Ratings 2 and 3 within this group are as follows:

Condition Rating 2 (Good) 57%

Condition Rating 3 (Fair) 43%

5.36 The above figures fail to reflect the predominantly Condition 2 (Good) defences along the fenland defences, apart from the Condition 3 defences along the left bank of the Helpringham South Eau. The reason for this bias is the inclusion of some 18km of the Cliff Beck and South Beck upstream of Helpringham in the NFCDD, almost all of which is in Condition 3, even though the classification of these as 'raised' defences is questionable.

CFMP Policies

5.37 The River Witham Catchment Flood Management Plan (CFMP), see Section 4, identifies the policies proposed for the long term management of flood risk in North Kesteven. These policies identify where future investment is required. The majority of North Kesteven's area is considered to be at little flood risk as there are only a limited number of people and properties at risk, such that the current level of flood risk management is all that is required.

5.38 For the Lower Witham Fens the policy is to take further action to sustain flood risk at its present level now and/or in the future. The action required to achieve this is to produce a detailed strategy to manage flood risk.

5.39 For the City of Lincoln, which includes a number of the large surrounding suburban villages in North Kesteven such as North Hykeham and Skellingthorpe, the policy is to take further action to sustain flood risk now and/or in the future. The action to achieve this is to provide additional flood storage upstream of Lincoln.

Waddington Low Fields

5.40 At Waddington Low Fields, on the southern edge of Lincoln, there is an extensive area of recent residential development along the eastern side of Brant Road. This area is situated at the foot of the Lincoln Edge and has a lengthy record of drainage problems, including flooding of some houses, caused by runoff from the scarp slope above Brant Road. This problem has been subject to two separate studies in 2005 and 2008.

5.41 The scheme chosen has been designed to intercept, store and discharge (at a controlled rate) surface water flows from the escarpment for up to a 1:100 year return period storm event, with an allowance for climate change.

5.42 The vast majority of the engineering operations, which include the excavation of an earth bund and associated catchwater drains and culverts, are situated in the open countryside beyond the Waddington (Brant Road) settlement curtilage. Other works that are to be undertaken within the settlement curtilage include the replacement of the existing piped drainage network in the Hollywell/Rowan/Brant Road area and improvements to the Boundary Dyke which ultimately discharges to the River Witham. Planning permission was granted for the works on 28th April 2009.

5.43 This area is identified on Figure 3.1 (Sheets 1) and is considered to be a critical drainage area. Further development in this area which will drain to this system will require a detailed FRA to be submitted to show how surface water will be dealt with.

Operational and Emergency Planning

5.44 In North Kesteven, as elsewhere in the Anglian Region, the Environment Agency has issued flood defence and land drainage emergency operational plans in conjunction with the local authority. These documents are intended to clarify areas of responsibility for the operation and maintenance of flood defence structures within the local authority's area and summarise the agreed joint emergency response by each of the public bodies involved.

5.45 Emergency planning within the County of Lincolnshire and its component LPAs operates under a Service Level Agreement whereby the County Council provide a core service which includes a Duty Officer on duty at all times. A member of the County's Emergency Planning Team is assigned specifically to each LPA in the County as an Emergency Planning Officer (EPO).

5.46 North Kesteven District Council is a Category 1 responder under the Civil Contingencies Act and, as such, is a member of the Lincolnshire Resilience Forum (LRF). The District Council is a signatory to all LRF plans and mutual aid agreements throughout the county and, if required, the County Emergency Planning Unit would request support from other regional authorities. If a major incident occurs and a Multi-Agency 'Silver Control' centre is opened North Kesteven will have a representative on the control team.

5.47 Serious flooding in North Kesteven or the surrounding area could trigger the declaration of a major incident. Should a major incident be declared, the Lincolnshire County Council (LCC)'s Emergency Plan and North Kesteven District Council's Emergency Plan would both be implemented. The District Council has no specific Flood Plan but the Council's Emergency Plan is designed to be generic and adaptable to meet all types of emergency, including flooding. At the district level, North Kesteven District Council provides an emergency telephone 'hotline' for (e.g.) the provision of sandbags etc.

5.48 The LCC's Emergency Plan may be found on the County Council's website, *www.lincolnshire.gov.uk* . Advice on action to be taken in the event of flooding may be found on this website and also on the District Council's website, *www.n-kesteven.gov.uk* .

5.49 Specific responsibilities and actions by the Environment Agency (EA), County Council and District Council are detailed in the following documents:

a) The EA's 'Local Flood Warning Plan'.

b) The EA's 'Flood Defence & Land Drainage Operational and Emergency Contact Arrangements for North Kesteven'.

c) Lincolnshire County Council's 'Emergency Plan'

c) North Kesteven District Council's 'Emergency Plan'.

A variety of other shorter publications are available for public information purposes, such as flooding advice leaflets, domestic emergency cards and business continuity cards. These are produced and issued on a county-wide basis to achieve economies of scale and ensure uniformity of approach and consistency of information across the county.

Flood warning

5.50 There are currently flood warning provisions in place for North Kesteven under which telephoned warnings can on request be sent to any property considered to be at risk of flooding. This is achieved by means of the Environment Agency's Automatic Voice Messaging (AVM) 'Warnings Direct' flood warning system and permits residents to take precautionary measures in advance of possible flooding.

5.51 The Environment Agency has divided the Witham catchment into a number of discrete Flood Warning Areas as shown in Figures E1 to E3 in Appendix E to the Witham CFMP. Those that fall within North Kesteven or cover parts of the District are as follows:

Upper Witham	PUWI-05	Claypole to Lincoln & R.Brant
	PUWI-09	Fossdyke Canal
Lower Witham	PLWI-01	Lower Witham Fens
	PLWI-02	Washingborough
	PLWI-09	Sleaford & Upper Slea
	PLWI-11	Heighington Beck
South Forty Foot Drain	PSFD-01	Fens West of South Forty Foot
	PSFD-03	Swaton

- This page left blank intentionally -

6 Climate Change

6.1 As mentioned in Section 3, the fluvial flood envelopes which appear on the Environment Agency's FZs were produced on a national basis using the J-flow modelling software and a topographical model based on natural ground level contours that automatically ignore all man-made intrusions in the landscape such as flood defences. The FZs were produced from J-flow model runs using hydrological estimates of current 1:100-year and 1:1000-year return period flood flows as inputs to the model.

6.2 The impacts of climate change have the potential to increase the river flows for the 1:100 and 1:1000 year flood events which could increase these flood envelopes. There are no published FZs showing the potential extent of FZ 3 and 2 in the future. For this SFRA it has been agreed with the Environment Agency that, taking a precautionary approach, in order to indicate the potential effect of climate change on the extent of the FZs, the planning authority should use the present day FZ 2 envelope as an indication of the possible extent of FZ 3 in 100 years time given the current predictions for climate change. This potential FZ 3 is shown on Figure 6.1.

6.3 The above assumption is made on the basis that broad-scale modelling, including topographical analysis, has been undertaken to produce the current FZ 2 outline, although not specifically to identify future extent of FZ 3.

6.4 When considering the availability of land currently shown to be within FZ 2 NKDC should consider that the land has the potential to be within FZ 3 in 100 years time and may require further detailed consideration of the impact of climate change before making a decision on the allocation of the land for development.

6.5 Similar modelling and analysis was undertaken for a 1:1000 year flood event, (0.1%), to give the current FZ 2. However, as no modelling or analysis was undertaken for flood events greater that the 1:1000 year event it is not possible to produce similar maps for a possible extent of FZ 2 with 100 years of climate change.

6.6 NKDC should note that any proposed land allocation currently shown to be within FZ 1, (<0.1%) but adjacent to the extent of the current FZ 2, (0.1%) will have the potential to be within FZ 2 in the future.

6.7 The potential increase in the limit of FZ 3 due to climate change is very slight. However, climate change could increase the probability of flooding to an area so that a flood event today that has a 1% chance of happening might have a 10% chance of happening in 100 years time.

- This page left blank intentionally -

7 Local Plan Sustainability Appraisal

7.1 Planning legislation requires that as part of the Local Development Framework preparation the Council is required to undertake Sustainability Appraisal (SA) incorporating Strategic Environmental Assessment (SEA) of potential future LDF local planning policies and Plans being developed. SA is a tool for assessing the impact of policies and proposals against a range of sustainability objectives so that decisions can be made that accord with the objectives of sustainable development. The first stage in the 5-stage Sustainability Appraisal process (Stage A) is the preparation of a *SA Scoping Report.*

7.2 The Council commissioned the work necessary for producing a Scoping Report for the Sustainability Appraisal of North Kesteven Local Development Framework documents. Following consultation undertaken, in collaboration with NK Planning Officers, the Final SA Scoping Report study (dated June 2008) was produced for the Council by Faber Maunsell Ltd.

7.3 A key output of the Study is its identification of 17 SA Objectives for North Kesteven along with a supporting SA Framework containing appraisal criteria The output of the research and consultation undertaken is the development of this range of local SA objectives, and an SA Framework, covering social, economic and environmental issues, all developed to assess the social, economic and environmental acceptability of future Council LDF documents, such as the Core Strategy.

7.4 After consideration by the Executive Board on 7 August 2008, the Full Council on 23 October 2008 considered the Final SA Scoping Report and resolved and agreed:

1. That the contents of the NK Sustainability Appraisal Scoping Study be noted and
2. That the Study be approved as one of the series of documents which form part of the evidence base required to inform the forthcoming Local Development Framework process, including the development of Local Development Documents.

7.5 The outcome of the research and consultation is therefore that the Council has a series of SA objectives. These are a key ‘tool’ to assess the sustainability of potential future local planning policies in LDF documents as they are planned and developed, including appraising potential options and alternatives considered in their preparation. The Sustainability Objectives are shown in Table 7.1.

7.6 This SFRA will help support the Sustainability Objectives, particularly Objective 17, by adopting the Sequential Test and Exception Test where required.

	Sustainability Appraisal Objective	SEA Topics
Social Aspects		
1	Develop sustainable communities to improve the quality of life for local residents.	Population and Human Health
2	Develop sustainable housing within the district across all housing types.	Population and Material Assets
3	Encourage sustainable transport, primarily by improving public transport so that it is accessible, efficient and affordable to all.	Population, Human Health and Climatic Factors
4	Improve provision of infrastructure and services in a sustainable way to meet demand, prevent emigration of young people and to support the ageing population.	Population and Human Health
5	Promote healthy and active communities by providing access to local green infrastructure (e.g. cycle routes and foot paths as well as leisure and sports centres).	Population and Human Health
6	Retain and continue to create safer environments within the district, reducing crime, the fear of crime and anti-social behaviour.	Population and Human Health
Economic Growth		
7	Promote economic growth that attracts investment in and development of new and existing large regional businesses and smaller local businesses and supports and encourages people to work and live in the district.	Population and Human Health
8	Encourage younger people to stay within the district by increasing the range and quality of opportunities available to them, promoting the value of existing sectors, and helping them develop the skills that are required within the district.	Population and Human Health
9	Promote local economic diversity, by encouraging innovation and diversification in existing economic sectors and investment in new sectors, primarily by encouraging higher technology businesses.	Population and Human Health
Effective Management of the Natural and Built Environment		
10	Identify appropriate brownfield sites and prioritise their development above the development of greenfield land and the most versatile/valuable agricultural land.	Material Assets, Flora, Fauna, Biodiversity, and Soil
11	Protect, maintain and improve biodiversity (potentially through habitat creation) and increase the available data on biodiversity in the district.	Flora, Fauna and Biodiversity
12	Minimise waste production and continue to improve recycling levels – reduce, reuse, recycle.	Flora, Fauna and Biodiversity
13	Protect, improve and enhance the quality and distinctiveness of the area's landscapes, townscapes and historic environment.	Population and Landscape and Cultural Heritage
Effective Management and Use of Natural Resources		
14	Encourage water conservation (households, commercial and industrial) particularly in the light of the predicted housing growth.	Water, Biodiversity and Human Health
15	Improve and protect natural resources (air, land and water) from exploitation and pollution	Air, Climatic Factors, Water, Flora, Fauna and Biodiversity, and Human Health
16	Improve energy efficiency levels and ensure sustainable and efficient design (which will reduce energy demand and promote renewable energy use).	Air, Climatic Factors, Water, Flora, Fauna and Biodiversity, and Human Health
17	Plan to mitigate and adapt to the effects of climate change, such as by reducing flood risk and by decreasing the carbon footprint of the population.	All SEA topics

Table 7.1 – Sustainability Appraisal Objectives

8 Sequential Test

8.1 PPS25 states that the risk-based Sequential Test should be applied at all stages of planning and the FZs are the starting point for the sequential approach. Where there are no reasonably available sites in FZ 1 decision makers allocating land in spatial plans should take into account the flood risk vulnerability of land uses and consider sites in FZ 2. Only where there are no sites available in FZs 1 and 2 should they consider the suitability of sites in FZ 3, applying the Exception Test if required.

Development Planning Sequential Test

8.2 North Kesteven District Council have drawn up two hierarchies of settlements, one for the Lincoln Policy Area and one for the remainder of the District, with four tiers of settlements in each hierarchy. This SFRA will consider the First and Second tier settlements as those most likely to be subject to further major development. and the Sequential Test be applied to these locations as follows:

Lincoln Policy Area - First Tier Settlements

North Hykeham

8.3 The main developed area is bounded on the North West by a narrow strip of FZ 3 and 2 arising from the IDB Pike Drain. The limit of the built up area to the South East is on the edge of a large area of FZ 3 and 2 arising from the River Witham. The major developed area is in FZ 1.

8.4 Further expansion to the east would be into FZ 3 and 2 and the Exception Test would need to be applied.

South Hykeham Fosseway

8.5 There is a very narrow strip of FZ 3 and 2 arising from an IDB watercourse which does not cover any of the built up area in South Hykeham or along the Fosse Way.

8.6 Further development should be in FZ 1.

Lincoln Policy Area - Second Tier Settlements

Bassingham

8.7 The River Witham runs to the west of the main village with a narrow strip of FZ 3 and 2. The built up area is shown to be in FZ 1.

8.8 Further development should be in FZ 1.

Bracebridge Heath

8.9 The village of Bracebridge Heath is shown to be in FZ 1.

8.10 Further development should be in FZ 1.

Branston

8.11 A very narrow strip of FZ 3 and 2 runs through the centre of the village. All the built up area is shown to be in FZ 1.

8.12 Further development should be in FZ 1.

Heighington

8.13 A narrow strip of FZ 3 and 2 arising from Heighington Beck runs on the northern boundary of Heighington.

8.14 Further development should be in FZ 1.

Metheringham

8.15 The village of Metheringham is shown to be in FZ 1.

8.16 Further development should be in FZ 1.

Skellingthorpe

8.17 Boultham Catchwater runs through the village of Skellingthorpe and has a narrow strip of FZ 3 and 2 affecting a number of existing properties in the existing built up area. The area of land north of the Boultham Catchwater and south of the Fossdyke Canal is covered by FZ 3 and 2 which extends to the limit of the District to the east. The major part of the built up area of the village of Skellingthorpe is shown to be in FZ 1.

8.18 Further development to the North of Boultham Catchwater, including the part of the district in the Lincoln Policy Area, (which includes Western Growth Corridor), will be in FZ 3 and 2 and the Sequential Test and, if required, Exception Test will need to be applied.

8.19 Further development taking place to the south of Boultham Catchwater and adjacent to the existing built up area will be in FZ 1.

Waddington

8.20 Waddington is shown to be in FZ 1.

8.21 Further development should be in FZ 1.

Washingborough

8.22 The area of land north of the main road and South of the River Witham and South Delph is covered by FZ 3 and 2. The main developed area is to the south of the main road and lies in FZ 1.

8.23 A narrow strip of FZ 3 and 2 arising from Heighington Beck runs on the southern boundary of Washingborough.

8.24 Further development should be in FZ 1.

Witham St Hughs

8.25 Witham St Hughs is shown to be in FZ 1.

8.26 Further development should be in FZ 1.

Rest of the District - First Tier Settlements

Sleaford

8.27 Parts of Sleaford are shown to be in FZs 3 and 2.

8.28 Sleaford is likely to be the focus for significant growth in the future.

8.29 Further development should take place in FZ 1 and only be identified to take place in FZ 3 following the successful application of the Exception Test.

8.30 Whilst the Exception Test does not apply to housing in FZ 2 NKDC should consider that, as land currently in FZ 2 has the potential to be within FZ 3 in 100 years time, they may require further detailed consideration of the impact of climate change before making a decision on the allocation of such land for development.

Rest of the District - Second Tier Settlements

Billinghay

8.31 Billinghay village is shown to be in FZ 1 with FZ 3 and 2 to the north east.

8.32 Further development should be in FZ 1.

Heckington

8.33 Heckington is shown to be in FZ 1.

8.34 Further development should be in FZ 1.

Navenby

8.35 Navenby is shown to be in FZ 1.

8.36 Further development should be in FZ 1.

Ruskington

8.37 A narrow strip of FZ 3 and 2 runs through the centre of the village.

8.38 Further development should be in FZ 1.

Development Control Sequential Test

8.39 Paragraph 4.15 of the PPS 25 practice guide states that “at the local level the Sequential Test should be applied to the whole LPA area”. Also paragraph 4.16 states that “for individual planning applications where there has been no Sequential Testing of the allocations in the LDD, the area to apply the Sequential Test will be defined by local circumstances relating to the *catchment area* for the development”.

8.40 Paragraph 4.31 states that “Through the Sequential Test, LPAs should identify areas where windfall development would be constituted as appropriate development i.e. defining the type of windfall development which would be acceptable in certain flood risk areas and what the broad criteria should be for submitting a planning application under these circumstances”.

8.41 Whilst this SFRA has considered the Sequential Test for potential land allocations in the First and Second Tier settlements it will still be necessary for the Sequential Test to be applied to individual planning applications.

8.42 In line with the advice contained in the locational strategy regarding the appropriateness of certain types of development, and also the requirements of other planning policies elsewhere within the local plan it is suggested that the following Sequential Test search areas are used for certain types of planning applications.

Development Type	Settlement Type	Sequential Test Search Area
Windfall residential development (new build dwellings)	Tiers 1, 2 and 3	**Tiers 1 and 2** – all land within the settlement curtilage with preference given to previously developed land. **Tier 3** – all land within the settlement curtilage provided that local need demonstrated and preference given to previously developed land in built up frontages. Windfall developments of a more strategic nature, coming in advance of LDF allocations, may require a district wide search area if it is felt that the scheme if approved could prejudice future development options and does not necessitate its location.
Permanent / short let caravan and camping	Tiers 1, 2 and 3 and open countryside	District-wide and subject to compliance with the requirements of Policy RST8 (or as superseded).
Employment uses	Tiers 1, 2 and 3	**Tier 1** – Sleaford & North Hykeham – all land within the settlement curtilage with preferential development of allocated employment sites or existing employment areas or employment sites with planning permission (Policy E1), then unallocated areas on previously developed land. **Tier 2** - Subject to compliance with the Locational Strategy (up to 5ha, local needs only) -all land within the settlement curtilage with preferential development of allocated employment sites or existing employment areas or employment sites with planning permission (Policy E1). **Tier 3** - Subject to compliance with the Locational Strategy (local needs only) all land within the settlement curtilage with preference to previously developed land in built up frontages.
Affordable housing exception sites	Open countryside	**Subject to an identified need through housing needs survey** – land within or immediately bordering the settlement in question.
New build agricultural / rural enterprise dwellings	Open countryside	All land within the agricultural holding.
Conversion of buildings in countryside to residential use (barn conversions)	Open countryside	District-wide - where alterations are proposed that increase the size of the building/s (e.g. over and above simple alterations to the external appearance) (see footnote 7, PPS25) 'Sequential Test not required where no/minimal alterations to the building are proposed. Please check the Sequential Test search area in each case with the Planning Officer.
Conversion of buildings in countryside to commercial use (barn conversions)	Open countryside	District-wide - where alterations are proposed that increase the size of the building/s (e.g. over and above simple alterations to the external appearance) (see footnote 7, PPS25) Sequential Test not required where no/minimal alterations to the building are proposed. Please check the Sequential Test search area in each case with the Planning Officer.

Table 8.1 - Sequential Test Search Areas

9 Exception Test

Application of the Exception Test

9.1 PPS25 states that the Exception Test should be applied, only after the Sequential Test, to Local Development Documents site allocations for development and used to draft criteria-based policies against which to consider planning applications.

9.2 For the Exception Test to be passed:

a) 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. If the Development Plan Document has reached the 'submission' stage the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal;

b) The development should be on developable, previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and

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

9.3 To inform the Exception Test it will be necessary to undertake further, more detailed Level 2 SFRAs for the following settlements as identified through the Sequential Test.

Settlements Requiring Level 2 SFRA

9.4 The following settlements all have an area of FZ 3 and 2 where there may be a need for future development to take place.

<u>Sleaford</u>

9.5 Sleaford is likely to be the focus for significant growth in the future

9.6 Further development should take place in FZ 1 and, where there is no available land in FZ 1, development should then be directed to FZ 2. Only where this is not possible should development be considered in FZ 3, and where necessary the Exception Test will need to be applied.

9.7 A Level 2 SFRA has been undertaken as part of this study to inform the Exception Test if required.

9.8 Whilst the Exception Test does not apply to housing in FZ 2 NKDC should consider that, as land currently in FZ 2 has the potential to be within FZ 3 in 100 years time, they may require further detailed consideration of the impact of climate change before making a decision on the allocation of such land for development.

<u>Fenland Area</u>

9.9 Although this is not a settlement area as identified in the local plan, due to its flat, low-lying topography, this area is covered almost entirely by FZs 3 and 2 and a Level 2 SFRA has been undertaken as part of this study.

<u>North Hykeham</u>

9.10 Any future development on land immediately to the east of the existing built up area towards the River Witham would be in FZ 3 and 2.

9.11 Further housing development can only be identified to take place in FZ 3 following the successful application of the Exception Test.

9.12 A Level 2 SFRA is being undertaken for this part of North Hykeham in FZ 3 as part of the SFRA for the Lincoln Policy Area to inform the Exception Test if required.

9.13 Whilst the Exception Test does not apply to housing in FZ 2 NKDC should consider that, as land currently in FZ 2 has the potential to be within FZ 3 in 100 years time, they may require further detailed consideration of the impact of climate change before making a decision on the allocation of such land for development.

Western Growth Corridor

9.14 Any future development in the part of the Western Growth Corridor, which lies in Skellingthorpe Parish, will be in FZ 3 and 2.

9.15 Further housing development can only be identified to take place in FZ 3 following the successful application of the Exception Test.

9.16 A Level 2 SFRA is being undertaken for this part of Skellingthorpe Parish (which excludes the existing built up area of the village) in FZ 3 as part of the SFRA for the Lincoln Policy Area to inform the Exception Test if required.

9.17 The major part of the built up area of the village of Skellingthorpe is shown to be in FZ 1.

10 Level 2 SFRA - Introduction

Planning Policy Statement 25

10.1 PPS25 states that where it is not possible to allocate all proposed development in accordance with the Sequential Test, taking into account the flood vulnerability category of the intended use, it will be necessary to increase the scope of the SFRA to provide information necessary for the application of the Exception Test..

10.2 The PPS25 FZs are based on the probability of river and sea flooding to which an area of land is currently subject, ignoring the presence and effect of existing flood defences or other man-made obstructions to flood flows

10.3 However, areas within the High Probability Zone (FZ 3), on fluvial or tidal floodplains, may have a standard of protection, due to established flood defences or their location within the floodplain, which reduces their probability of flooding. This degree of flood risk to which these areas are subject may well be significantly less than that implied by their PPS25 FZ, provided that those defences are maintained at their current standard of protection. The reduced probability of flooding, allowing for the defence, is called in this report "Actual Flood Risk"

10.4 Potential development areas in different parts of FZ 3 may be at different level of actual flood risks, particularly in an area with flood defences. However, whilst the probability of actual fluvial flooding may well be less than 1%, because of the defences, the area will still fall within FZ 3. In order to apply the sequential approach to areas within the FZs the LPA will need to rank development according to actual flood risk.

10.5 This more detailed assessment of flood risk within specific study areas constitutes a Level 2 SFRA as described in PPS25.

10.6 To give full benefit to the Districts Council's planners, any assessment of flood risk within the two study areas identified as being possible locations for potential development will provide an evaluation of actual flood risk over the whole of those study areas. This will be expressed as the probability of flooding when the flood defences are taken into account and include what the impact of climate change will be.

10.7 This will enable the Council to apply the Sequential Approach required by PPS25, both as regards the variation of flood risk within a study area and also for the practical purpose of ranking areas within FZs 2 and 3 in accordance with their respective degree of actual flood risk.

11 Actual Flood Risk

Introduction

11.1 In order to establish the actual level of flood risk it is necessary to understand how flooding is developed within the District, understand the history of flooding, and establish any affect man-made features can have on actual flood risk.

11.2 The actual flood risk to the two study areas is described in Sections 14 and 15.

Causes of Flooding

11.3 Flooding can be caused by:

- Overflowing of watercourses;
- Breaching of Embankments;
- Mechanical, Structural or Operational Failure of engineering installations, (i.e. pumping stations);
- Floodlocking and Tidelocking and;
- Localised Flooding.

For full descriptions and explanations see Appendix B.

Historical Flooding

11.4 North Kesteven District Council, the Environment Agency, the Black Sluice, Witham First District, Upper Witham and Newark Area Internal Drainage Boards and Anglian Water were all contacted during the study to obtain information on flooding records and drainage problems in North Kesteven. The responses received are summarised below. From the responses received, there appears to have been no significant or widespread flooding from either fluvial sources or arterial drainage systems within North Kesteven since 2002.

<u>Environment Agency</u>

11.5 The Environment Agency (Anglian Region) provided a set of four Historic Flood Maps of North Kesteven. These featured the flood envelopes for the March 1947 (Lincoln area), February 1977 (Sleaford), April 1981 and 1993 (Barlings Eau / Middle Witham) and November 2000 (Upper Witham) flood events. These historic event flood envelopes are shown in Figure 11.1.

11.6 In the North Scarle area the Environment Agency (Midlands Region)'s Historic Food Map shows the flood envelopes for fluvial flooding from the River Trent in 1795, 1932 and 1947. The 1795 flood envelope, although somewhat inconsistent, shows extensive flooding along the Fossdyke between Torksey and Lincoln, extending from North Scarle to Stow Park in the north and, within North Kesteven, inundating large areas of land in the North Scarle, and Skellingthorpe areas and extending as far east as Lincoln. In the Eagle area the 1795 flood envelope extends for about 500m across the Wigsley Drain into North Kesteven. Northwest of Doddington the same flood envelope extends on either side of Carr Lane beyond Old Hag Farm.

11.7 The 1947 flood covered a much smaller area, extending into North Kesteven over an area of farmland west of North Scarle but not reaching the village itself. According to the Agency's Historic Flood Map the 1932 flood did not affect any land or property in North Kesteven. The 1795 and 1947 flood envelopes are shown in Figure 11.1.

11.8 Appendix D in the Witham CFMP gives a schedule of historic flood events for the whole of the Witham catchment. Some of the information given is very scant, confined to a date and river (e.g. Nov.1954 Fossdyke Canal) but all fluvial flooding events recorded in the CFMP with a specific reference to locations in North Kesteven are listed in chronological order. There appear to be some errors and duplicated entries in the record. Reference is made in the CFMP to groundwater flooding in Sleaford in 1997 but this record does not appear in Appendix D of the CFMP and is believed to be confusion with the groundwater flooding which occurred in 1977.

North Kesteven District Council

11.9 Despite the extreme weather conditions and resultant severe flooding that affected much of Lincolnshire, Nottinghamshire and Yorkshire on 25th/27th June 2007 no serious flooding of a strategic nature was reported in North Kesteven. There were, however, over two hundred reported incidents of local flooding throughout North Kesteven at this time. All of these incidents were the result of a combination of factors associated with the heavy rainfall, such as inadequate surface water drainage capacity, saturated soil conditions and possibly floodlock conditions. The District Council maintains a record of requests for sandbags received from members of the public during flood events and a summary of this record for the years 2002 to 2007 inclusive is given in Table 11.1 below.

Location	2002	2003	2004	2005	2006	2007	Totals
North Scarle			1			7	8
Skellingthorpe	11		2			8	21
Haddington	1					5	6
North Hykeham	33					28	61
Welbourn						14	14
Waddington	26	1				36	63
Washingborough	5		2			17	24
Heighington	5			1		31	37
Dunston						4	4
Metheringham	3				1		4
Scopwick & Kirkby Grn	1					5	6
Digby		2				4	6
Sleaford	12	1	1	1	1	15	31
Heckington						6	6
Scredington						3	3
Helpringham						7	7
South Kyme						3	3
Other Locations	14	2	1			28	45
Totals	111	6	7	2	2	221	349

Table 11.1 - Summary of Requests for Sandbags in North Kesteven, 2002 to 2007

11.10 Only those locations where more than two requests for sandbags were received in any year are named. All other requests are aggregated under 'Other Locations'. It should be noted that many requests for sandbags are made on behalf of a group of properties. On the other hand a request for sandbags does not necessarily imply that a property was subsequently flooded or would otherwise have been flooded. Requests are prompted by public perceptions of impending flooding or a fear of flooding.

11.11 Table 11.1 does nevertheless give a good indication of those locations where flooding of clusters of properties tends to recur and of the variability of flooding events from year to year. It should also be emphasised that, as far as we are aware, none of the incidents recorded in Table 11.1 occurred as a result of fluvial flooding (i.e. flooding on a strategic scale) but from local surface water drainage systems being either defective, blocked or overwhelmed by the severity of the storm event.

11.12 Waddington Low Fields, has a lengthy record of drainage problems, including flooding of some houses, caused by runoff from the scarp slope above Brant Road. The area again suffered from flooding in the major event in Summer 2007 and the District Council has detailed records of the extent to which individual properties in the area were (or were not) affected. These records are summarised in Table 11.2 below.

Location	**Flooding reported in ---**		
	House	**Garage / Outbuildings**	**Garden**
Acacia Ave.	0	4	3
Almond Cres.	0	3	6
Ashby Close	0	2	5
Belvoir Close	0	0	5
Brant Road	3	25	55
Cedar Close	0	4	4
Chestnut Grv.	1	4	2
Fir Tree Ave.	0	3	9
Greenwood Cl.	0	0	0
Hawthorn Ave.	0	7	4
Holywell Rd.	3	16	47
Lime Cres.	2	6	4
Maple Close	0	1	3
Mulberry Cl.	0	0	0
Pine Close	0	10	12
Redwood Dr.	1	17	16
Rowan Road	0	8	10
Sherwood Dr.	0	2	9
Sycamore Dr.	0	0	3
Thoresby Cl.	0	0	3
Valley Road	0	5	9
Walnut Cl.	0	1	0
Willoughby Ln.	0	2	2
Totals	**10**	**120**	**211**

Notes: 1) Where a house is recorded as flooded, the garage / outbuildings and garden were also flooded.

2) Where garage /outbuildings are recorded as flooded, the garden was also flooded.

3) The figures in Table 11.2 are based on information from householders.

Table 11.2 - Flooding at Waddington Low Fields, Summer 2007

11.13 The incidence and location of flooding and drainage problems recorded in 2007 appear to have been similar to that experienced in previous notable events. It should, however, be emphasised that nowhere in the flooded area did the depth of flood water in any dwelling house exceed 65mm and in all but one of the flooded houses the depth of flood water was 25mm or less. These shallow depths are characteristic of localised surface water flooding. Section 5 (paragraphs 5.40 to 5.43) has details of the improvement scheme implemented to reduce this flood risk.

Black Sluice IDB

11.14 Flooding occurs regularly in Swaton after heavy rainfall but this is a result of overflow from Swaton Eau. This watercourse is a Main River which is not maintained by the Board and for which the Board has no responsibility, although the impact of the flooding is felt solely within the Drainage District.

11.15 In the Board's upland catchments there has been no flooding recorded in the Asgarby Beck catchment (tributary of the Heckington Eau) or in the smaller catchment south of Heckington in the past forty years. In the Cliff Beck and North Beck catchments there has been occasional flooding of riparian fields but no properties have been affected. A property on Mareham Lane, Spanby has in the past been in danger of flooding from Spanby Beck but the Board have recently taken over a section of this watercourse in the Mareham Lane area and the flood risk to this property is now reduced.

11.16 A cottage adjacent to the Threekingham Drain at Mareham Lane, Threekingham was flooded in 1999 and again in 2000. The owner has subsequently erected a floodwall to protect his property. The Board believes that there are no other properties in Threekingham at risk of flooding from this watercourse although adjacent gardens can become inundated after heavy rainfall.

Witham First District IDB

11.17 Flood events in the District since 1945 have, in the main, resulted from the breaching or overtopping of high level carrier (Main River) floodbanks. The principal events occurred as follows:-

1947 Flooding from Branston Delph into Heighington Fen.

1960 Flooding from South Delph into Washingborough Fen, and
flooding from Billinghay Skirth into Billinghay and North Kyme Fens.

2007 Flooding from Sandhill Beck into Washingborough Fen,
flooding from Heighington Beck and Car Dyke into Heighington Fen, and
flooding from Car Dyke into Metheringham Fen.

Upper Witham IDB

11.18 The Upper Witham IDB's website has a detailed description of the great Trent Flood of February 1795. This, like the 1947 flood, was the result of snowmelt on frozen ground. In 1795 the Trent flood bank at Spalford was breached and 20,000 acres of land between the Trent and Lincoln were flooded. Most of the flooded areas were outside North Kesteven but there was substantial flooding in the Skellingthorpe and Boultham areas. The embanked line of Lincoln High Street formed a barrier to the eastward passage of flood waters, but thereby presumably exacerbated the impact of the flood west of Lincoln. The inundation persisted for three weeks.

11.19 Further flooding took place along the Trent in 1824 and 1852, although there is no record that either event affected North Kesteven. After the latter event efforts were made to close the 'gaps' in the low natural ridge along the east bank of the Trent at Spalford, Newton, Torksey and Marton.

11.20 The Board's records indicate that flooding also occurred in the North Kesteven part of their Drainage District in 1947, 1954, 1958, 1959, 1960, 1965, 1968, 1977, 1979, 2000 and 2007. Much of this flooding would have been relatively minor and, in any case, there have been considerable improvements to the Board's arterial drainage systems in recent years, particularly in response to flooding, as well as improvements to Main Rivers.

Newark Area IDB

11.21 In 2000 the area flooded by overspill from the Mill Dam Dyke south of Girton Lane extended as far east as North Scarle village where two properties were flooded to the east of Church Lane.

11.22 The Board's Engineer also reports that there was flooding in the Mill Dam Dyke catchment in 2004, and again in Summer 2007 when there was a considerable loss of crops on agricultural land. In 2007 there was also flooding from an unmaintained riparian watercourse at Morton Hall and on Camp Road, Witham St Hugh's from a blocked culvert under the old Swinderby airfield.

Man Made Flood Risk Sources

11.23 Many other flood risk sources, other than structures specifically intended as flood defences, may also have a significant effect on flood risk and create a local discrepancy between inherent and actual flood risk. These man-made sources, which should be taken into account in site-specific FRAs, are summarised below.

IMPOUNDING RESERVOIRS

11.24 There are no large impounding reservoirs in the Witham catchment which could have a significant influence on flood flows in the River Witham or any of its major tributaries. There are, however, a number of small raised reservoirs in North Kesteven sufficiently large (i.e. with more than 25,000 cu.m of water stored above the natural ground level) to be subject to the provisions of the Reservoirs Act of 1975.

11.25 The Environment Agency maintains a statutory register of all reservoirs subject to the Act and has provided a list of all 'large raised reservoirs' in North Kesteven. This list is given in Table 11.3 below.

Reservoir	Volume Stored (cu.m)	Type	Max Ht of Dam	Date
Culverthorpe Lower Lake	120,000	Earth dam. Impounding	6m	1740
North Hykeham Sailing Lake	132,000	Earth dam. Impounding	1m	1987
Bardney Raft Pond	55,900	n/k Non-Impounding	3.7m	1900
Witham Washlands	6,300,000	Earth dam. Impounding	2.5m	1990
Mount Lake, Asgarby.	915,000	Earth dam. Non-Impounding	8.4m	2004
Thurlby Lake	930,000	Earth dam. Impounding	3m	n/k

Table 11.3 Large Raised Reservoirs in North Kesteven

11.26 North Hykeham Sailing Lake and Thurlby Lake are both large disused gravel pits now used for recreational and amenity purposes. Although formally classified as Impounding Reservoirs their natural catchments are small. Water levels in both lakes are heavily influenced by percolation through the underlying sand and gravel strata and the general water table in the area. Neither reservoir is considered to pose a serious flood risk to land downstream.

11.27 At North Hykeham Sailing Lake the Pike Drain flows parallel with the northern edge of the reservoir and the lake's only natural catchment is the strip of land between the lake and the A1434 road. Thurlby Lake has a larger natural catchment (3.05 sq.km) which lies to the west of the lake and drains to the River Witham, 1.6 km to the east. Although Thurlby village is situated downstream of the lake, adjacent to the river, the village is situated on an 'island' above the 10 metre contour.

11.28 Bardney Raft Pond is the largest of a group of bunded sludge lagoons on the west side of the River Witham, once associated with the now disused Bardney Sugar Factory on the opposite side of the river. This reservoir is situated in open country between the embanked river and Dales Head Dike and is not considered to pose a significant flood risk.

11.29 Mount Lake near Asgarby is a modern bunded reservoir constructed to store water for spray irrigation purposes. It is situated in open country on the edge of the fens in the angle between the Sleaford – Boston and the Sleaford – Spalding railway lines. It is not thought that its failure would pose a significant flood risk.

11.30 Culverthorpe Lake is the only conventional impounding reservoir in North Kesteven and was constructed in the eighteenth century as an ornamental and amenity lake for the nearby Culverthorpe Hall. The lake is fed by the North Beck (1.86 sq.km catchment) which passes through the tiny village of Swarby nearly 3km downstream of the lake.

11.31 The low embankment across the River Witham and its valley floor east of South Hykeham and the control sluice through which the river flows constitute the dam that creates the Witham Washlands upstream. The sluice is only operated and the washlands filled during flood events, which means that the reservoir embankment is only subject to hydraulic loading very infrequently. Although the Lincoln City boundary is only one kilometre downstream of the embankment, this modern and professionally engineered structure is not considered to present a flood risk to the city.

11.32 Denton Reservoir, which provides a water supply to the upper reaches of the Grantham canal is situated 4km west of Grantham near the head of Old Beck (Foston Beck), a tributary of the Upper Witham. This C18 reservoir is 250m upstream of the Canal, 12km upstream of the confluence of the Foston Beck and the River Witham, and 22km from North Kesteven's southern boundary. Any uncontrolled release of water from Denton Reservoir would be intercepted by the Grantham Canal and much of it would flow west along the canal to the Devon (Trent) catchment. Old Beck is conveyed beneath the canal in a culvert, the limited capacity of which would throttle any flood flow down the beck, and the limited channel capacity and flat gradient of the beck between the canal and the River Witham would greatly attenuate any flood flow before it reached the District boundary. Denton Reservoir is therefore considered to pose only a very minor flood risk to North Kesteven.

RUNOFF STORAGE LAGOONS

11.33 North Kesteven District Council has compiled a list, reproduced in Table 11.4 on the next page, of runoff balancing and attenuation ponds throughout the District. These are understood to be ponds or lagoons that have been specifically designed for the purpose of attenuating surface water runoff from recent urban developments. Although no technical details have been provided, they are all believed to be relatively small. Two of the ponds in Heighington, Stephenson Way and Edward Baker Road, also accept runoff from highways.

Parish	Location
Heighington	Edward Baker Close
	Millstream
	Stephenson Way
	Stoyles Way
	Turnberry Close
Metheringham	Shiregates
North Hykeham	Lincoln Fields
Skellingthorpe	Lancaster Way
Sleaford	Clay Hill Road
	Spire View
Washingborough	Canterbury Drive
	Fen Road
Witham St Hughs	Rosehip Walk
	Sorrel Road
	Village Pond

Table 11.4 - Runoff Balancing Ponds in North Kesteven

11.34 The District Council has also produced schedules of recent (1991 to 2008) works involving 'lagoons' and 'ponds' from their planning applications database. Most of the 37 ponds listed in that schedule appear to be small excavated ponds for amenity, conservation or fishing purposes with few if any flood risk implications. The much smaller number of lagoons listed, ten in all, cannot be readily classified from the descriptions given and only two, at Heckington and Burton Pedwardine, are described specifically as "earth banked lagoons".

<u>CANALS</u>

11.35 The Fossdyke Canal, which connects the River Trent at Torksey to the Witham at Lincoln, has already been described in some detail. This waterway is, in effect, a backwater of the River Witham and in hydraulic continuity with it throughout as there are no locks between Lincoln and Torksey. Although the western end of the canal appears to be largely man-made the eastern end is a canalisation of the River Till. The Fossdyke is substantially wider and deeper than most English canals and still carries a considerable boat traffic, although this is now confined to pleasure craft.

11.36 The Sleaford and Horncastle Canals are now, for all practical purposes, the principal river channels of the Rivers Slea and Bain respectively. Although both these rivers are major tributaries of the Witham, the Bain is no longer navigable and the Slea is only navigable at its downstream end. Their canalisation has virtually no effect on flood flows in the River Witham and both the Slea and the Bain discharge to the Lower Witham where that river leaves North Kesteven.

11.37 Because the River Slea is now routed along the old course of the Sleaford Canal between Sleaford and Ewerby, the river is slightly embanked above the adjacent low-lying land.

11.38 The 7km section of the western end of the Grantham Canal is situated in the Upper Witham catchment. Even if a breach in the canal banks occurred where it crosses either Old Beck (Foston Beck) below Denton Reservoir, or Mow Beck, upstream of Grantham, it is not considered to pose any real flood risk to North Kesteven.

LOCKS, WEIRS & SLUICES ALONG THE WITHAM

11.39 The River Witham is a navigable river from Lincoln to the Wash. When the river navigation was improved in the eighteenth century, locks were constructed (or reconstructed) at Lincoln (Stamp End), Bardney, Kirkstead and Boston (Grand Sluice). The lock at Kirkstead was removed when the river was subsequently widened and deepened. None of the locks were associated with mill weirs. The Stamp End and Grand Sluice locks are integral with sluice structures through which the full range of river flows is discharged. Bardney Lock is associated with a more complex configuration of channels described below.

11.40 On the upstream of side of Lincoln, flood flows in the River Witham are diverted into a lower level flood relief channel, the Sincil Dyke, through a sluice at Bargate Weir. Downstream of Lincoln the Sincil Dyke (here known as the South Delph) converges with the Witham and they follow closely parallel but independent routes from Washingborough to Horsley Deeps, immediately downstream of Bardney Lock, where the South Delph joins the Lower Witham, with which it is in hydraulic continuity. The sluices at Bargate and Stamp End were reconstructed and modernised in connection with the Lincoln Washlands Flood Alleviation Scheme.

11.41 The main channel of the River Witham flows through the centre of Lincoln and down the river's high level navigable channel between Stamp End and Bardney Lock. At Fiskerton Sluice, 2km upstream of Bardney Lock, the old lower-level course of the River Witham - the Old River Witham - diverges from the navigable channel which it rejoins at Horsley Deeps, below Bardney Lock.

11.42 The sluices at Bargate, Stamp End and Fiskerton are all used to control flood flows in the River Witham and apportion flows between the navigable channel, the Old River Witham and Sincil Dyke (South Delph). All three channels converge at Horsley Deeps, 36km upstream of Boston, to form the Lower Witham. The operation of these sluices will not therefore affect flows downstream of Horsley Deeps or have a significant impact on flood risk within North Kesteven below Bardney.

FLOOD ALLEVIATION WORKS IN THE LINCOLN AREA

11.43 Flood alleviation works also constitute anthropogenic influences on flood risk although, unlike other anthropogenic influences, their specific purpose is the reduction of flood risk. The three principal flood alleviation schemes which have a significant impact on flood risk in North Kesteven have already been described in some detail but will be considered briefly again here in the context of the potential residual flood risk that they could themselves present. Their designed standard of service and beneficial impact on flood risk in North Kesteven has been taken into account in the hydraulic modelling of the Upper and Lower Witham river systems and is inherent in the flood risk probabilities given for that system and they have not, therefore, been considered separately in that respect.

Upstream of Lincoln – the Lincoln Flood Alleviation Scheme

11.44 The Lincoln Flood Alleviation Scheme (FAS) comprises two off-line flood storage areas upstream of Lincoln, one on the Upper Witham near South Hykeham and the other on the River Till near Saxilby. At both locations, under normal conditions the river flows unimpeded through a control sluice erected across the river channel. In a flood event the sluice gates are partially closed, restricting the flow through the sluice, thereby impounding the water behind the sluice and diverting the flood water through an inlet/outlet sluice in the river bank into the flood storage reservoir which has been created by a low earth embankment across the river valley. When the flood peak has passed the sluice gates are opened gradually and the impounded water released back into the river in a controlled manner.

11.45 The control sluice on the Upper Witham is situated 100m downstream of its confluence with the River Brant and there are therefore two inlet/outlet sluices. One is in the left (west) bank of the Witham immediately upstream of the control sluice and the other is situated in the left bank of the Brant 1,300m upstream of the confluence.

11.46 There are two ways in which either of these two installations could themselves pose a residual risk of flooding to land and property downstream. The first would be if the 2.5m high embankments across the valley, 1.2km and 1.5km long respectively, breached at the height of the flood, releasing a large volume of impounded flood water into the Upper Witham or the River Till. This is very unlikely as both embankments are of modern, professionally engineered construction and neither is subject to a large head of water.

11.47 The other potential residual risk event would be the failure to close (or open) a sluice gate and utilise the available flood storage, or to close the control sluice gates too early or too late. In any of these events the impact of the failure would be felt primarily in Lincoln itself. At both locations the impact within North Kesteven upstream of Lincoln would be localised. The Upper Witham control sluice is only a short distance upstream of the North Kesteven boundary. Flood risk from a breach in the Fossdyke Canal's banks triggered by a failure of the River Till control sluice would in North Kesteven be confined to the low-lying land between the canal and the Boultham Catchwater Drain.

11.48 When the Lincoln FAS was constructed in the late 1980s the river control sluices were equipped with tilting weirs consisting of steel gates set between sluice piers and operated by hydraulic rams. The hydraulic rams were subsequently found to be unsatisfactory and the tilting gates are now operated by a system of wire ropes and electric winches.

Downstream of Lincoln – Branston Island

11.49 Since Branston Island is filled by gravity from the adjacent channel of the Old River Witham near Bardney Lock, the level of water on the island is never higher than the level in the river system below Bardney Lock (the River Witham between Bardney and Boston, the Old River Witham and the South Delph) at the height of a flood event. Only when the flood peak in the river has passed and the water level in the river falls substantially below that within the island will there be an appreciable head difference on either side of the embankment around the island, although by this time the Environment Agency should have commenced releasing water stored within the island back to the river to restore the Island's flood storage capacity in case there is a second flood event in the river.

11.50 The structural failure of the embankment surrounding the island is thus a remote residual risk possibility and would only occur when the main flood peak has passed and flood levels in the river have fallen considerably, thereby greatly reducing impact of any such failure on flooding downstream.

11.51 A failure to operate the sluices to permit the inflow of flood water into storage in Branston Island at the correct time – either too early, too late, or not at all - would increase flood risk along the Lower Witham downstream of the island in North Kesteven.

Downstream of Lincoln – the Lower Witham Flood Alleviation Scheme

11.52 As the Lower Witham FAS does not include any new flood defences or introduce any new structures whose failure would be likely to result in an increase of flood risk behind those defences or elsewhere, the consequences of any residual risk failure of this scheme or its components can be disregarded.

11.53 Although not, strictly speaking, part of the Lower Witham FAS, a failure of the pointing doors at the outfalls from the Delphs, Billinghay Skirth or Kyme Eau into the Witham under flood conditions could result in a much greater volume of flood water entering a fenland flooding compartment if a breach occurred in a floodbank along one of the Delphs or the other tributaries. Although the probability of flooding would not be increased, its impact could be significantly increased.

South Forty Foot Drain

11.54 With the exception of the Head Dyke (Skerth Drain), none of the outfalls to the South Forty Foot Drain from its high-level tributaries - Helpringham Eau, Helpringham South Beck and Swaton Eau - are equipped with pointing doors to prevent reverse flow into the tributary.

LOCKS, WEIRS & SLUICES ALONG THE RIVER SLEA

11.55 The lower, embanked reaches of the River Slea are currently navigable from the River Witham at Chapel Hill to Cobblers Lock, 5km upstream of South Kyme. There is an intermediate navigation lock (Kyme Lower Lock) at Terry Booth, 2.5km from Chapel Hill. There are bypass channels and flow control structures at both locks which will have finite conveyance capacities.

11.56 Upstream of Cobblers Lock the old navigation channel has been retained as the principal river channel. Originally there were five navigation locks between Cobblers Lock and the head of the navigation at Sleaford (Haverholme, Papermill, Holdingham, Bonemill and Cogglesford Locks). Although the lock chambers still exist, the lock gates and all associated mechanisms have been removed. None of these locks have bypass channels and the whole of the flow in the river now passes through the old lock chamber.

11.57 A small, manually operated sluice in the right (south) bank of the River Slea at East Banks in Sleaford allows water to be discharged from the river (navigation channel) into the head of the Old River Slea to maintain flows in the old river, but this sluice plays no significant role under flood conditions.

Residual Flood Risk

11.58 Residual risks of flooding arise either from extreme events with exceptionally high return periods (e.g. 200+ years) or from events which, due to their unpredictable nature, their probability of occurrence is not readily amenable to quantitative evaluation. This type of event may arise from premature structural failure, serious operational or equipment failures, and incidents of sabotage, vandalism etc, or freak accidents which cannot be foreseen.

11.59 The principal residual risk in North Kesteven would be a premature failure of a fluvial flood defence embankment well before the embankment was overtopped. Such a failure would occur during an event significantly less severe than that for which the embankment had been designed, although the actual probability of the residual risk event occurring could still be very small indeed. Such a failure could arise from a variety of causes - burrowing animals, structural weaknesses or human action. Clearly the residual risk of such premature failure can be reduced to insignificance if the embankment has been competently constructed, regularly inspected and adequately maintained.

11.60 The failure of pumping plant at land drainage pumping stations also constitutes a potential residual risk, but any resultant flooding is generally slow to materialise and there is usually adequate time for the responsible authority to take emergency action to repair or replace the defective equipment.

11.61 The failure of a major tidal outfall sluice (such as the Grand Sluice at Boston) - either a mechanical malfunction of the sluice gates or a collapse of the structure itself - is also a residual risk. This could have two consequences; a failure of the sea doors to close, resulting in an inflow of tidal water, or a failure of the land doors to open fully, resulting in the impounding of flood water upstream.

11.62 The nature of the former failure - the failure of the sea doors to close - would be such as to restrict the rate of inflow of tidal water through the sluice for a limited period, and since there would almost certainly be a large ponded reach of river upstream of the sluice, the impact of a restricted inflow over a single tide peak would be relatively minor. It would, however, be essential to take emergency action to prevent further inflows on successive tide peaks.

11.63 The failure of the land doors to open fully at the start of a fluvial flood event could be more serious. The storage capacity available in the ponded length of river upstream of the sluice will normally be adequate for a single period of tidelock when discharge to tidal waters is impeded or prevented, but if free discharge of flood water to tide during the interval between successive tidelock periods is prevented, then the storage capacity may be taken up and the ponded section of river overflow its banks. Flooding may then ensue. The replacement of the traditional timber land doors (with their ‘mitre gate’ design) with modern steel vertical lifting gates at Grand Sluice since 1980 has, however, greatly reduced the residual risk previously associated with potential operating errors at this sluice.

11.64 A catastrophic fluvial flood on the Trent could result in flood water breaching the defence line along the A1133 road and reaching Lincoln down the corridor of low-lying land along the Fossdyke in a repeat of the great flood of 1795. The Trent’s flood defences have been massively improved over the past two centuries and this would now constitute a residual risk with a remote possibility of occurrence.

12 Flood Hazard

Flood Hazard Zones

12.1 In a major flood event, where a river is confined within flood defences there may be an appreciable difference between the water level on one side of the flood defence and the ground level in the defended area behind that defence. If that defence were then to fail, whether through the collapse of a floodwall or the breaching of an embankment, there would be a sudden inrush of flood water into the defended area. The velocity and depth of water cascading through the breach could, initially at least, be sufficiently great to sweep people off their feet resulting in their death by injury or drowning. The premature failure of a flood defence structure is by its nature a residual risk, but its potentially fatal consequences dictate that it be given equal consideration in flood risk assessment.

12.2 As flood water pours through a breach it will fan out across the hinterland behind the defences, and its velocity and depth will both decrease with distance from the breach. This will be determined by the flood level / ground level difference (head of water), the width of the breach, and the land surface topography behind the breach. PPS25 and its Practice Guide specify the determination of a Rapid Inundation Zone and also refers to Flood Risk in Assessment Guidance for New Development Phase 2 R & D Technical Report FD2320.

12.3 For this SFRA the three Flood Hazard zones as referred to in FD2320 will be used as follows:

- Danger for Some
- Danger for Most
- Danger for All

12.4 Hazard Zones in specific study areas are a major component of a Level 2 SFRA.

12.5 The definition of the Hazard Zones is that contained in FD2320 which uses a matrix of flood flow velocities and depths to define the categories of ‘Danger for Some’, ‘Danger for Most’ and ‘Danger for All’. Technical Report FD2320 also presents an equation which give a quantitative definition of Flood Hazard in terms of velocity, depth and a ‘debris factor’ which is intended to take into account the impact of flood-borne debris on flood hazard.

12.6 In order to determine the extent of the Hazard Zone at any location it is necessary to set up a dynamic two-dimensional (2D) hydraulic model of the breach scenario, from the moment when the breach occurs to the time when the velocities and depths of the flood water pouring through the breach have reached their maximum values at all points across the hinterland or flood compartment into which the water is flowing. Setting up this model for each breach scenario requires a knowledge of the head of water in the high-level watercourse at the moment the breach occurs and during the time when water is flowing through the breach. It also requires a detailed representation of the topography of the land surface in the flood compartment behind the breached defence. The river models used to provide an estimate of the head of water and the sources of data used to provide the topographical details are described later in this Section.

12.7 In the 100-year flood event scenario for which the Hazard Zone was determined, in the great majority of cases the creation of a Hazard Zone would be as a direct result of a breach. Overtopping of itself would rarely result in flooding both deep and fast flowing enough to meet the Environment Agency's hazard criteria. However, in a residual risk event a flood defence could breach prematurely, well before that defence is overtopped. The "Hazard Zone" is therefore independent of the probability of flooding and, irrespective of mapping clarity considerations, should properly be plotted separately. The methodology used is described in greater technical detail in Appendix B.

12.8 In order to give a realistic representation of the Hazard Zone it was assumed that the breach occurred at the peak of the flood hydrograph in the embanked river and that the head of water driving the flow through the breach did not remain constant after the breach but diminished thereafter in accordance with the flood hydrograph in the embanked river and the release of water from the ponded section of river. The effects of secondary and tertiary defence lines in obstructing the passage of flood water across the land surface were also allowed for in the ground surface model.

12.9 It should be emphasised that the Hazard Zone is simply the area behind a flood defence line within which people could be at risk following a breach in that defence line. Since a breach can occur either as a result of overtopping or as a result of a premature (residual risk) failure of a flood defence, the Hazard Zone is not associated with a specific probability of occurrence. It is a worst-case representation of the Hazard Zone envelope derived from the assumption of a series of breaches at intervals along the primary defence line in that area.

12.10 Furthermore, although the probability of a breach following the overtopping of a flood bank in (say) a 100-year event will be ten times more likely than an equivalent breach in a 1000-year event, the impact of the 1000-year event breach, as regards the extent of its hazard zone, will not be significantly greater than that of the 100-year event breach, as the difference between the 100 and 1000-year flood levels in the embanked watercourse may be very small compared with the total head of water acting on the defence line.

Impact of Climate Change

12.11 Climate change is predicted to increase river flows by 20% over the next 100 years. This increase in flows will increase the probability of overtopping and therefore the chance of a breach.

TOPOGRAPHICAL SURVEY DATA AVAILABLE FOR HAZARD MAPPING

12.12 A number of sources of data and information are available which can be used to establish the topographical component of the 2D breach scenario models used to establish the various envelopes shown on the Hazard Zone maps. These are :-

LiDAR data

12.13 The Environment Agency has established a national database of topographical spot-level data derived from an airborne laser imaging process. Contoured plots of LiDAR (Light Detection and Ranging) data are of greatest use in open country as the presence of buildings is found to give rise to clearly anomalous results in built-up areas, even with automated filtering of the data to remove the effects of buildings, trees and other obstructions. LiDAR data is available with a vertical resolution of ± 0.1m on a 2m horizontal grid.

12.14 Even though the LiDAR data coverage does not extend over the whole country, it has now reached the point where the great majority of FZs 2 and 3 are included. When the original SFRA was undertaken there was little if any LiDAR coverage in North Kesteven. Since 2002 this situation has been remedied and when the current study was carried out the LiDAR coverage of the District, supplied in electronic format by the Environment Agency, was largely complete, apart from the following gaps:

1) The Lincoln Edge between Waddington and Wilsford. This is mainly elevated land along the crest of the limestone ridge but included a small area on the floor of the Witham (Brant) Valley west of Navenby.

2) The North Scarle / Swinderby / Eagle area. It is not clear whether this gap reflected a real gap in the coverage or because the area is in the Agency's Midland Region (i.e. not in the Anglian Region).

Gaps in the LiDAR data can, where necessary, be filled using Ordnance Survey SAR data.

Ordnance Survey Maps

12.15 1/25,000 scale OS maps are contoured at 5m intervals which is adequate to give a general indication of the shape of the fluvial or tidal floodplain at any location. The contours are supplemented by spot heights to the nearest 1m on roads. Unfortunately since most fenland is below 5mOD, the 1/25,000 map contours are of limited use in this area. It should also be noted that road levels, particularly in floodplains and fenland, can be significantly higher than adjacent land levels.

12.16 A complete 1/10,000 scale OS map coverage of North Kesteven was provided by the District Council on a CD which can be accessed using "MapInfo" software. The District Council also supplied OS Mastermap mapping of the District at 1/50,000 scale and 1/25,000 scale, the latter purchased specially for this study.

Ordnance Survey 'SAR' Data

Ordnance Survey Synthetic Aperture Radar (SAR) data coverage is obtained from aircraft or earth observation satellites. It is, however, less accurate than LiDAR data, with a vertical resolution of only ± 0.5m and a 5m horizontal grid. It can, however, usefully be used to infill gaps in LiDAR data coverage.

River Models

Lower Witham

12.17 The Lower Witham river model based on ISIS hydraulic modelling software extends from approximately 300m downstream of Stamp End Sluice in Lincoln to Boston Dock. It incorporates the Barlings Eau and the watercourses to the west of the River Witham in North Kesteven - the Delphs, Billinghay Skirth, and the lower end of Kyme Eau.

12.18 The Lower Witham modelling was originally undertaken in 2005 and the ISIS model is currently being updated using InfoWorks RS software and with new hydrological inputs. However, the updated version of the model is still being calibrated has not yet been run for any design events. The Lower Witham model also includes the Lower Witham Flood Alleviation Scheme and, from its impact on river flows through Lincoln, the effects of the Lincoln FAS.

12.19 The 2005 model was not run for the 1000-year return period flood event or for 'with climate change' scenarios. There is a minimal increase in flood level between the 25 and 100-year return periods because for events above the 10-year return period widespread overtopping of the defences is occurring, with flood water pouring into the adjacent fens like water from an overflowing bath.

River Slea / Kyme Eau

12.20 Only the lower reaches of the River Slea (the Kyme Eau) as far as upstream as Cobblers Lock have been incorporated into the current Lower Witham hydraulic model. A separate hydraulic model of the middle and upper reaches of the River Slea is at present being developed and although it will ultimately be coupled to the Lower Witham model it is not expected to be complete, calibrated and able to produce flood level estimates until later in 2009. This new river model will supersede an earlier hydraulic model of the Slea completed and run in 2003. In the absence of more recent modelling results, flood level estimates derived from the 2003 model have been used in this study.

12.21 The 2003 river model constructed using MIKE 11 software modelled the River Slea / Nine Foot River / Old River Slea system from Cobblers Lock through Sleaford to Wilsford. The model was calibrated against the flood event of January 2003. Although this event did not give rise to any significant flooding in Sleaford, sensitivity testing showed that the model was stable for variations in model parameters. The modelling results indicated that the 100 year and 200 year flood events would remain within the river channels through Sleaford and no flooding would occur, although localised flooding upstream of Sleaford was considered possible.

12.22 In order to investigate the effects of climate change on flood levels, all fluvial inputs to the model were increased by 20%. Although the study was carried out under PPG25, the 20% increase in river flows corresponds to that advocated in PPS25 for the situation to the year 2115. The ‘with climate change’ results obtained from the 2003 model can therefore still be regarded as applicable.

South Forty Foot Drain

12.23 An ISIS hydraulic model of the South Forty Foot Drain was constructed in 1999 for the Environment Agency’s Black Sluice Strategy Study but an updated South Forty Foot (Black Sluice) model has since been constructed and calibrated for the Agency’s Witham Catchment Strategic Model (WiCSM) project using InfoWorks RS (IWRS) modelling software. This supersedes the 1999 ISIS model although the appropriate hydrological inputs have not yet been generated for the new WiCSM IWRS model so the earlier ISIS model is the only one currently available for design runs. It should, however, be noted that the Strategy Appraisal Report cited above was not ‘signed off’ by the Agency.

12.24 There are three different versions of the ISIS model. The 'Breaches' version contains vertical sluice units which are triggered by levels in the channel to represent a breach into each flood compartment. These units were placed at the location considered most likely to breach in each compartment. In the 'Spills' version, breaches are removed or deactivated so that flood compartments are flooded only by overtopping at spills and not by breaches in the defences. The 'Contained' version assumes neither spills nor breaches and that flood water is contained in-channel throughout the high-level river system.

12.25 There are no 1 in 1000yr event results or ‘with climate change’ results available for the South Forty Foot Drain.

13 Study Areas

13.1 The location of the two study areas for which more detailed (Level 2) flood risk assessments are required are shown in Figure 1.2.

13.2 The degree of actual flood risk throughout each study area, expressed in terms of Flood Risk Categories, has been assessed from a combination of factors, sources of information and engineering judgment. Flood risk is assessed as current flood risk - no allowance can be made for enhanced flood risk within the study area which could arise as a result of inappropriate future development. If the predicted effects of climate change over the next century have been found to be sufficient to transfer a study area or land within a study area to a higher Flood Risk Category this will be stated in the assessment.

13.3 Flood risk sources considered in the Level 2 assessment include all open watercourses (rivers, streams, canals, arterial drains and riparian drains) and, where applicable, principal surface water and combined (foul + surface water) sewers. Possible flooding from foul sewers is not included in the assessments as this can occur from a variety of causes, often with no direct or quantifiable relationship to extreme rainfall events.

13.4 Although both low and high flows in the River Slea and the smaller streams draining the Lincolnshire Limestone outcrop are heavily influenced by groundwater, there are no records of groundwater flooding as such in either study area. Nevertheless, the flooding which occurred in the Slea catchment in 1977 (Figure 11.1), although it was confined to agricultural land upstream of Sleaford and did not, as far as we are aware, affect the town itself, bore all the indications of groundwater-derived flooding.

13.5 The limestone aquifer beneath Sleaford and much of the Lower Witham fens is confined beneath Oxford Clay and is under considerable artesian pressure. There is a history of abandoned private water supply boreholes, especially in the fens south of Sleaford, going “wild” and overflowing in an uncontrolled manner but the volume of groundwater issuing from “wild” boreholes is far too small to pose any flood risk and riparian owners have always been able to channel it away to the local drainage network. “Wild bores” can represent the loss of a valuable water resource but they are not a flood risk.

13.6 Flooding from canals is of no direct relevance in either of the two North Kesteven study areas. Even though the route of the old Sleaford Canal passes through both study areas the canal has for many years been utilised solely as a land drainage channel in the Sleaford Town Study Area and primarily as a land drainage channel in the Lower Witham Fens Study Area and is operated as a high-level watercourse in both. It should, however, be noted that the Fossdyke Canal presents a real flood risk to low-lying land in the Skellingthorpe area.

13.7 The risk of flooding of a development site is not the only consideration. The potential increased flood risk posed by the urbanisation of a "greenfield" development site to other areas downstream of the development site also has to be evaluated. This risk can arise not only from the additional runoff volumes and higher peak runoff rates generated by newly impermeable areas but also from the reduction in natural floodplain storage capacity if the development takes place in a floodplain.

13.8 The two study areas are very different in character. The relatively small (251ha) Sleaford Town study area is almost wholly urban and is situated where the River Slea leaves the limestone uplands to the west but before it enters the fens. In direct contrast, the extensive (177sq.km) but sparsely populated Lower Witham Fens study area consists entirely of intensively farmed level fenland which is defended from flooding from the adjacent high-level watercourses by raised earth embankments. Virtually the whole of this study area falls within the Agency's FZ 3.

13.9 Urban development within a floodplain raises the question of 'displaced water' and the potential loss of natural flood storage volume within the floodplain, though if the development is within a defended floodplain the issue only arises with floods of greater magnitude than that for which the floodplain's defences were designed. If the loss of floodplain storage can be shown to be of significance for flood risk elsewhere then consideration should be given to the provision of compensatory flood storage volume within the floodplain to mitigate the effects of the 'displaced water'.

13.10 Many small surface watercourses within urban areas in North Kesteven have been partially or wholly culverted in the past. In some areas many of these watercourses had been designated as Critical Ordinary Watercourses (COWs) and were subsequently adopted as Main Rivers by the Environment Agency, but only three such watercourses have been identified in North Kesteven. None of these is situated in either of the two study areas.

13.11 Other culverted watercourses, particularly in Sleaford, now form part of Anglian Water's surface water sewer network, with outfalls direct to IDB-maintained drains or Main Rivers. In some areas these sewers can be of considerable size at their downstream ends and thus constitute potential flood risks over a significant area, but past experience has shown that this does not appear to be the case in North Kesteven. The larger surface water sewers have nevertheless been taken into account in the Sleaford Town study area flood risk assessment and, where appropriate, are shown on the study area plan. A set of plans showing the principal hydrological and hydraulic features in each study area are presented as Figures 13.1 and 13.2. These plans should be read in conjunction with the appropriate FZ maps (Probabilities) and Hazard Zone maps.

Flood Risk Assessment for Study Areas

13.12 The individual flood risk assessments for the two study areas will be presented in a common format in Sections 14 and 15, under the following headings:

a) General description of the study area

b) Hydrology of the study area (including hydraulic structures etc)

c) Flood risks within the study area

d) Flood risks to downstream areas

Flood Hazard

13.13 The area immediately behind the flood defence line within which a serious risk to life and limb could occur is known as the Hazard Zone. The Hazard Zone and its determination have already been discussed in some detail in Section 12.

13.14 In a built-up urban area, the flow of water into the defended area behind a breach is very unlikely to conform to a uniform pattern. The actual pattern of flow through a breach, and hence the width of the hazard zone at that point, will be distorted by the presence of buildings, walls, street furniture, parked vehicles, etc.

13.15 The flood risk assessments of the study areas made in Sections 14 and 15 for strategic planning purposes do not preclude the necessity for site-specific flood risk assessments of individual development sites within the wider study areas. The flood risk assessments of the study areas should nevertheless be used as a general framework within which site-specific flood risk assessments are undertaken.

14 Sleaford Town Study Area

13.16 The study area flood risk assessments in Sections 14 and 15 apply to the present day situation. The predicted effects of climate change will result in a general increase in flood risk throughout North Kesteven and in the two study areas.

General Description of the Study Area

14.1 The boundary of the study area is that of the Sleaford curtilage line shown on Inset Map No.52 in the North Kesteven Adopted Local Plan 2007. The irregularly shaped study area extends over about 560 hectares (compared with 1,838 ha for the whole of Sleaford parish) and measures approximately 3km from both north to south and from east to west. The general layout of the study area is shown in Figure 13.1.

14.2 The River Slea flows from west to east through the centre of the study area. The river forms a prominent visual feature within the town centre and through the public open spaces on the eastern edge of the town. Within the town centre the river is bifurcated and flows in two separate channels; the River Slea itself and the Nine Foot River on a parallel course to the south.

14.3 The Sleaford Canal was constructed in the mid 1790s and reached the town from a junction with the navigable River Witham at Chapel Hill. The eastern half of the canal through the fens was formed by canalising the River Slea but its western half was created by utilising a series of millstreams along separate route to the north of the river. The canal was fed with water from the River Slea at its upstream (Sleaford) end, with flood flows diverted down the old course of the River Slea at a sluice just downstream of the town. When the navigation ceased in the 1878 the lock gates were removed and the canal became the main channel of the River Slea between Sleaford and the fens.

14.4 From the western end of the built-up area, the River Slea runs parallel with Electric Station Road, separated from the road by the row of house along the north side of the road. Downstream of Castle Causeway the river runs along the north side of West Banks as far as Water Gate. It crosses under West Gate, Sleaford's main shopping street, and then beneath Carre Street before entering the old canal basin. The old canal basin, an arm of which has been infilled, is situated on the eastern edge of the town centre.

14.5 The Nine Foot River diverges from the Slea in open country 400m west of the study area at Guildhall Springs. It then follows a separate course, south of Alexandra Road and then, downstream of Castle Causeway, along the north side of the castle site. The Nine Foot River crosses West Gate between Jermyn Street and West Banks, but rejoins the Slea before reaching Carre Street.

14.6 Within the historic town centre the narrow channels of the Slea and Nine Foot River are both closely confined by buildings, although recent urban redevelopment has been encouraged to create more open space and visual amenity along the river channels.

14.7 Not all of Sleaford drains directly to the River Slea system within the town. Holdingham Beck follows the northern boundary of the study area for about 1km between Lincoln Road (B1518) and Sleaford Wood. The northern end of the study area, north of Galley Hill, drains to the Beck. Holdingham Beck is a tributary of Leasingham Beck which joins the River Slea at Haverholme, 4km downstream of Sleaford. To the south of Grantham Road (A153) the southern end of the study area drains to Moor Drain which discharges via Cliff Beck and Helpringham Eau to the South Forty Foot Drain.

14.8 The majority of the study area consists of the existing built-up urban area of the town but also includes areas of ongoing housing development on the fringes of the town in the Holdingham (Stokes Drive), New Quarrington (Oak Road) and Quarrington Hill (Clay Hill Road) areas. The study area also includes a large area of 'greenfield' land in its north-eastern quadrant, notably on Sleaford Moor between the railway (Loop Line) and the Sleaford Northern Bypass (A17) and between East Road and the Old River Slea. There are smaller areas of 'greenfield' land within the study area at Quarrington (Northfield Road) and north of Bass Maltings.

14.9 The Sleaford Town Study Area straddles the River Slea which divides it into two halves, north and south of the river respectively. North of the river the ridge which forms the watershed between the Slea and Holdingham Beck catchments runs east from North Rauceby and then curves to the south of Holdingham to terminate east of North Gate / Lincoln Road as Galley Hill. The crest of the ridge falls from 32mOD at the Sleaford Western Bypass (A15) to 28mOD on the study area's eastern boundary and 22m on Galley Hill where it peters out.

14.10 To the south of the town, the ridge that forms the watershed between the Slea and the South Forty Foot catchment runs north east from Rauceby Hospital to Quarrington and then generally along the line of Grantham Road to end at Sleaford Railway Station. At the Sleaford Southern Bypass and the study area's western boundary the ridge crest level is 27mOD but thereafter it falls steadily to about 17mOD at the railway station.

14.11 Along the Slea itself, ground levels fall slowly from 15mOD on the western edge of the study area at the Loop Line to 10mOD at the eastern boundary near Bonemill Bridge. On the north side of Galley Hill, ground levels along the line of Holdingham (Field) Beck fall steadily from 24mOD at Holdingham to 16mOD at Northfield Farm and then more gently to 13mOD at the A17/A153 junction on Sleaford Moor. South of the Quarrington ridge ground levels fall steadily to 17mOD at the Town Road / London Road (A15) junction and to 13mOD where the study area boundaries cross Mareham Lane and Boston Road.

14.12 Parts of the study area fall within areas administered by Internal Drainage Boards (IDBs). A considerable area of housing in the Milton Way / Russell Crescent / Mark Avenue area on the eastern edge of the study area is in the Black Sluice Drainage District, as well as a much smaller area of land on the southern edge of the study area in the vicinity of Mareham Lane (Keepers Way). On the eastern side of the study area a corridor of land along the River Slea and Old River Slea falls within the Witham First Drainage District. On the western side of the study area a detached part of the Witham First Drainage District extends down the Slea and Nine Foot River as far Castle Causeway.

Hydrology of the Study Area

14.13 The hydrology of the Sleaford Town study area is dominated by the primary flood risk sources identified and evaluated previously in this Report - the River Slea, the Nine Foot River and, to a minor extent, the Old River Slea. However, the northern and southern edges of the study area fall drain to the Holdingham Beck and Moor Drain respectively. The possibility of groundwater flooding in the study area will also be considered. The following paragraphs will therefore deal with the various flood risk sources within the study area.

<u>River Slea (Including Old River Slea & Nine Foot River)</u>

14.14 A general description of the River Slea has already been given in Section 4. Upstream of Sleaford the river has a predominantly rural catchment with a catchment area of 48 sq.km. The river rises near Ancaster, 8 km west of Sleaford and, until Wilsford, has a perennial flow, but dredging of the section of the channel between Wilsford and Rauceby in the 1960s exposed the alluvial gravels and resulted in a substantial loss of water from the river to the underlying limestone aquifer at times of low flow.

14.15 The River Slea flows east through the Ancaster Gap, a glacial overspill channel through the Lincolnshire Limestone ridge. Ground levels at Ancaster itself are only marginally above 40mOD but the watershed on the limestone ridge to the north and south of the Gap rises to 114mOD and 123mOD respectively.

14.16 The Nine Foot River rises in Quarrington Fen on the south side of the River Slea, 1,300m upstream of Castle Causeway, Sleaford. At its upper end normal water levels in the Nine Foot River are marginally below those in the parallel reach of the River Slea. Although the substantial base flow Nine Foot River is fed by springs west of the town (Cobblers Hole and the Guildhall Spring) it can also be fed by a gravity discharge from the River Slea at its upstream end through the Cranwell Line Sluice. This sluice is normally kept closed but is operated by the Environment Agency to balance flows and levels in the Slea and Nine Foot River in flood conditions.

14.17 Water levels through the town in both the Slea and the Nine Foot River are controlled by the manually operated Carre Street tilting gate weir which is located downstream of their confluence. This weir is understood to be intended primarily to maintain water levels in the two river channels through the centre of the town at times of low flow. There is a sluice-operated bypass culvert on the south side of the weir.

14.18 Water levels in the 600m section of the River Slea between Carre Street and Cogglesford are controlled by the tilting weir at the upstream end of the old lock chamber at Cogglesford Mill. Similarly the 600m reach of the river between Cogglesford and the railway bridge on the eastern boundary of the study area is controlled by the low weir across the head of the old lock chamber at Bonemill Lock. Downstream of Cogglesford Mill the river channel - the old navigation channel - follows the northern edge of its floodplain and the south (right) bank of the channel is slightly embanked.

14.19 Water can be discharged from the River Slea into the head of the Old River Slea by means of the Swimming Baths Sluice which is situated in the south (right) bank of the Slea 350m upstream of Cogglesford Mill. This sluice consists of a penstock and a small rectangular aperture which allows overflow from the Slea when water levels exceed the aperture's cill level. Under flood conditions (such as in June 2007) the penstock is opened manually to release flood flows from the Slea to the Old River Slea.

14.20 In the late 1980s, problems were being encountered with low flows in the River Slea through the town under drought conditions, leading to minimal water levels in the river channel giving rise to stagnant water and environmental degradation. In response to the problem a river support borehole was drilled on the north bank of the river south of Bristol Way, feeding a pipeline which discharges groundwater into the river just downstream of the Loop Line railway bridge on the western edge of the study area. This borehole is only operated during drought conditions and has no impact on flood risk in the town.

14.21 Flows in the River Slea (Wilsford Beck) are gauged at a gauging station just upstream of Wilsford sewage treatment works, and another at Leasingham Mill, 3.5km downstream of Sleaford. The Leasingham flow record (1974 to date) includes the 1977 flood peak which, at 5.16 cu.m/sec is 45% higher than the next highest flood peak recorded in the 35 year period of record at that gauge. The Wilsford flow record commences in 1992, although it is known that this gauging station had been in operation since the mid-1980s.

<u>Holdingham Beck</u>

14.22 Holdingham Beck (also known as Field Beck) is a tributary of the River Slea and flows from west to east through Holdingham. It has a slightly elongated catchment area of 3.0 sq.km. upstream of Holdingham Bridge (B1518). The catchment which extends as far west as North Rauceby is predominantly agricultural. It lies on the dip slope of the Lincolnshire Limestone and can therefore be expected to exhibit the hydrological characteristics typical of that geology - relatively high permeability and a smooth flood hydrograph with a moderate peak.

14.23 Holdingham Beck forms the study area's northern boundary for a distance of 850m, from just upstream of Lincoln Road (B1518) to Northfield Farm where it turns to flow NE towards the Sleaford Northern Bypass (A17). The Beck is culverted under the bypass and a further 1,700m downstream it reaches the Sleaford to Coningsby (A153) road where it enters the Witham First Drainage District. East of the A153 it continues as an IDB-maintained drain on a line roughly parallel with the River Slea into which it discharges downstream of Haverholme Lock, having merged with Leasingham Beck 700m SE of the A153/B1188 junction at Ruskington Moor Farm.

Moor Drain

14.24 Moor Drain is a relatively minor watercourse maintained by the Black Sluice IDB. It rises on high land above 25mOD in the vicinity of the old Rauceby Hospital, 3km SW of Sleaford town centre. The IDB-maintained watercourse commences on the southern boundary of the study area at the junction of Quarrington Town Road and London Road and flows SW alongside London Road for 450m and then joins the main channel of Moor Drain which comes in from the west at this point. Under normal conditions the majority of the flow in Moor Drain originates west of London Road rather than from the IDB drain from Quarrington which runs alongside London Road.

14.25 The combined watercourses flow east from London Road in a well defined stream channel to a confluence with Cliff Beck 400m south of Lodge Farm. Cliff Beck becomes a Main River downstream of Mareham Lane and is, in turn, a tributary of Scredington North Beck and Helpringham Eau. The Moor Drain catchment (area approximately 3.2 sq.km) includes much of the built-up area of Sleaford south of Grantham Road although outside the study area the southern two thirds of the catchment is predominantly agricultural.

14.26 Land levels within the catchment fall steadily from about 25mOD along the Quarrington ridge to marginally above 10mOD where Moor Drain leaves London Road, but they then fall much more gently to just below the 10metre contour at Moor Drain's confluence with Cliff Beck. The area of land between Lodge Farm and London Road is therefore virtually level. Unlike the more permeable southern slope of the Quarrington ridge, the soils of the larger, 'greenfield' part of the Moor Drain catchment are more clayey and therefore less permeable.

Groundwater

14.27 Under natural conditions, the Lincolnshire Limestone aquifer which sustains flows in the streams draining the scarp slope south of Lincoln (including the River Slea) and other streams overflows along the spring line where the exposed limestone aquifer dips beneath the overlying Oxford Clay. In the Slea catchment the spring line occurs just upstream of the town and the river is fed by a major springs at Boiling Wells Farm which sustained a substantial base flow in the river. The geological configuration of the limestone and clay strata mean that the confined limestone aquifer east of the spring line (and beneath Sleaford itself) is under artesian pressure.

14.28 Large scale abstraction of water for public water supply and other uses in recent decades has reduced the artesian pressure in the aquifer and diminished the outflow from the Boiling Wells Farm springs, notably in late summer and autumn before winter recharge of the aquifer commences. This in turn resulted in a considerably diminished base flow in the River Slea (and other spring-fed streams in the area) during dry periods, causing considerable ecological and amenity problems in the river channel through the town but this problem has now been resolved.

14.29 In the nineteenth century, the presence of an artesian aquifer beneath the expanding town provided a readily available supply of high quality water for public supply, commerce and industry and many small businesses and farms had their own boreholes, but over the years many of these small boreholes have been abandoned and lost. In some cases they start to leak and as the artesian water is chemically aggressive this leakage is progressive and the borehole becomes 'wild', discharging uncontrollably under artesian pressure. There have also been instances where the redevelopment of a 'brownfield' site has inadvertently damaged the buried headworks of a lost but still sealed borehole, again resulting in the uncontrolled release of artesian water from the damaged borehole. In both cases localised flooding can occur until the 'wild' borehole is sealed or the flow diverted to a watercourse.

14.30 In neither case is the flooding described above of strategic concern, but planners and developers of ‘brownfield’ sites in the Sleaford Town study area (and elsewhere in the artesian zone in North Kesteven) should be aware of this potential minor flood risk problem.

Flood Risk within the Study Area

14.31 The Environment Agency’s FZs Fig.3.1 (Sheet 7) show parts of the Sleaford Town Study Area to be in FZ 3. This pattern is summarised below.

Upstream of Castle Causeway Electric Station Road, Alexandra Road and Castle Causeway. Also open land (Sleaford Fen) between River Slea and Nine Foot River.

Castle Causeway to Carre Street West Banks, King John Street, Castle Terrace Road, Castle Street, Thomas Street, Martins Court, Jermyn Street (W end), South Gate (N end) and Carre Street (Central section).

Carre Street to Hoplands Bridge Wharfside Mews, Kesteven Street (S end), Ambulance Station, and NKDC Offices (S end). Also open land between River Slea and Old River Slea.

Hoplands Bridge to Bonemill Bridge Corridor of open land along the line of the Old River Slea.

However, the results of the hydraulic modelling of the River Slea published in the March 2003 report suggest that there would be no flooding in Sleaford for the 100-year, 200-year and 100-year with climate change events.

14.32 A subsequent report, (River Slea and Nine Foot River - Study Report by Atkins) , issued in June 2003 considered the town’s flood defences in more detail. Sections of raised flood defences - floodwalls and floodbanks - were identified in a number of locations. These are summarised in Table 14.1 below.

Waterc’se	Location	Type	Bank of w’cse	Approx. Length	Defence Level (mOD)	200-yr Fld Lvl (mOD)
R.Slea	From Loop Line Rly Br to W end of Electric Stn Rd	Bank	R	150m	15.30	14.99
R.Slea	New Street f/bridge to Old R.Slea Sluice	Bank	R	250m	13.88*	13.23
R.Slea	New St f/br to East Gate	Bank	L	400m	13.80	13.25
R.Slea	Old R.Slea Sluice to Avoiding Line Rly Br.	Bank	R	900m	12.60	11.68
R.Slea	Just d/s of Avoiding Line Rly Br.	Bank	R	300m	12.29	11.35
R.Slea	Between Avoiding Line Rly Br and Bonemill Ln.	Bank	L	200m	11.87	11.07
R.Slea	Between Avoiding Line Rly Br and Bonemill Ln.	Bank	R	300m	11.76	11.07
9 Ft River	Opposite Castle Field	Wall	L	200m	14.46	14.03
Old R.Slea	Between Avoiding Line Rly Br and Bonemill Ln.	Bank	L	100m	10.55	8.74

Note: * June 2003 report gives Defence Level as 14.59mOD in Table 4.2 but 13.88mOD in Table 4.3.

Table 14.1 - Raised Flood Defences in Sleaford

14.33 It should be noted that the only lengths of raised flood embankment upstream of New Street are a short length of bank upstream of Electric Station Road and a length of floodwall along the Nine Foot River opposite Castle Field. The June 2003 Atkins report concluded that if any of the raised flood defences failed during a major (100 or 200-year) flood event, the only properties at risk of flooding would be houses at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated.

14.34 The Slea catchment upstream of Sleaford drains an area of exposed Lincolnshire Limestone and is therefore highly permeable. Most of the rain falling on the catchment infiltrates rapidly to the limestone aquifer and thence there is a relatively small risk of flooding from heavy, intense rainfall. Such catchments exhibit a high base flow component, sustained by major spring flows from the aquifer at the edge of the confined zone, and flows in these rivers rise and fall slowly, the antithesis of a 'flashy' river draining (e.g.) a clay catchment which rises (and falls) rapidly in response to rainfall. Historically, urban development in settlements along such rivers has tended to adapt to the characteristic copious but steady flow in the river.

14.35 However in exceptional circumstances, after a period of prolonged heavy rainfall over weeks rather than days, the water table in the aquifer rises well above its normal overflow level at the springs and the aquifer then discharges to the river and its normally dry tributaries over a wide area. Because the resultant flood flow can be an order of magnitude larger than the usual 'flood' flows in the river, the groundwater-derived flooding that then occurs can appear to be unprecedented in its impact and extent, and because of the catchment's slow natural response, groundwater flooding can also be of considerable duration.

14.36 Because a spring-fed river through a town has become regarded as safe and benign, with a relatively constant flow of clear water, urban development tends to crowd in on the river and its channel becomes hemmed in. Where in the late nineteenth and early twentieth century the local aquifer became a readily available source of public and private water supply, natural water levels in the aquifer were depressed. This may have depleted the dry weather spring-fed flow in the river, creating amenity, water quality and ecological problems (as at Sleaford) but the risk of already rare groundwater-derived flooding was reduced even further.

14.37 Although the effective channel capacity through the centre of Sleaford comprises both the Nine Foot River and the Slea itself, given the size of the catchment the size of both channels in the town centre downstream of Southgate (see photographs) is notably constricted, certainly when compared with the size of the two channels at Castle Causeway and the combined channel at East Banks. This illustrates the phenomenon described in the paragraph above. It is clear that the parallel channels downstream of Southgate constitute a significant constriction for flood flows, and would certainly create a serious water level afflux upstream.

14.38 The fact that only a single record of flooding in the centre of Sleaford has been brought to our attention suggests that groundwater flooding in the town is a relatively rare event. Nevertheless, if it does occur the restricted hydraulic capacity of the river channels through the town centre suggests that its impact is likely to be disproportionately severe. In may be significant that the Environment Agency's Historical Flood Map for the 1977 event (Figure 11.1) only shows any flooding upstream of Castle Causeway, almost entirely on the low-lying land south of the Slea. The only domestic properties that appear to have been affected were the back gardens between Electric Station Road and Alexandra Road. This suggests that in a moderate event the extensive area of low-lying land (Sleaford Fen) between the town and its western bypass acts as a flood storage area, filled by overflow from the Slea, and provides the town centre with a considerable degree of flood protection.

14.39 Anglian Water's sewer plans of Sleaford shows the town's principal sewers as foul, rather than combined flow sewers and there are no significant storm overflows in the town. Even so, it must be assumed that the foul sewerage system, particularly in the town's older central core, convey some storm runoff. There must therefore be a possibility of residual risk flooding from the town's sewerage system but its impact is likely to be localised and relatively minor.

14.40 Sleaford's foul sewage is conveyed primarily by gravity to a sewage treatment works adjacent to the River Slea on the north side of the A17 road. Treated effluent and storm overflow from the works is discharged to the Old River Slea. There is a junction of three large foul sewers near the Old River Slea Sluice (East Banks), a 650/1090mm sewer from Eastgate, a 750/825mm sewer from the London Rd / Grantham Rd area and a 600mm sewer from Mareham Lane. The resultant trunk sewer continues to the sewage works in a 1090/1220mm pipe along a route parallel with and to the south of the Slea. A separate 675mm foul sewer reaches the sewage works from the Galley Hill area.

14.41 Anglian water have recently carried out improvements to the foul sewerage system in the Jubilee Crescent area of Sleaford, and there are currently no specific areas of the town known to be at risk of sewer flooding.

14.42 Sleaford has a number of disparate and relatively small, local surface water sewerage systems rather than one or two large comprehensive systems. All the town's surface water sewer systems rely on gravity discharge and most are associated with recent residential developments. These systems discharge variously to the Slea, the Nine Foot River, the Old River Slea, Holdingham Beck, the Galley Hill and Drove Lane Drains and to tributaries of the Moor Drain, as well as to minor watercourses in the Mareham Lane and Kirkby la Thorpe areas. None of these small surface water drainage systems is considered to present a serious flood risk at the strategic level.

Actual Flood Risk

14.43 The result of the hydraulic modelling as described above indicates that flooding would not occur for the 1:100 or 1:200 year events, so the probability of flooding is <0.5%.

Impact of Climate Change

14.44 The above hydraulic modelling also indicated that there would be no flooding to Sleaford for the 100 year event with climate change.

Flood Hazard

14.45 The June 2003 River Slea and Nine Foot River - Study Report by Atkins contains the best information available and concluded that if any of the raised flood defences failed during a major (100 or 200-year) flood event, the only properties at risk of flooding would be houses at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated. Detailed flood hazard mapping has therefore not been undertaken for Sleaford as there are no major raised defences or significant areas that would be impacted from a breach. The flood extent, should the defences fail, is shown on Figure 14.1

Flood Risk to Downstream Areas

14.46 The great majority of the storm runoff from the Sleaford Town study area discharges to the River Slea or the Old River Slea. Storm runoff from the study area entering Holdingham Beck finds its way into the Slea downstream of Haverholme Lock and the Old River Slea enters the Slea immediately downstream of Cobblers Lock. The Slea itself discharges to the Lower Witham at Chapel Hill. Only the relatively small amount of storm runoff from the southern edge of the study area finds its way to the South Forty Foot Drain system via Moor Drain, Cliff Beck and Helpringham Eau.

14.47 Although any additional storm runoff from urban development within the study area will make only a very minor contribution to flood flows in the Lower Witham and South Forty Foot river systems, both these high-level systems constitute a significant flood risk to the extensive areas of fenland through which they pass. In addition, the South Forty Foot Drain outfall is partially pump-drained at Black Sluice in Boston and any additional storm runoff entering the system in a flood event will impose an extra pumping cost at Black Sluice.

14.48 It is evident from the above that runoff from any part of the Sleaford Town study area will enter a fluvial drainage system with not only a relatively high probability of flooding (albeit primarily of open fenland) but with a potentially major impact over an extensive area. It is therefore important to ensure that all surface water runoff from any future development in the study area is attenuated to existing rates of runoff from the development site. This attenuation should allow for the predicted effects of climate change on increased storm rainfall and runoff from the development over the next hundred years.

Conclusion

14.49 Whilst parts of this study area are shown to be in FZ 3 and 2 the defences that exist reduce the risk of flooding and detailed modelling shows that the flood risk is reduced to less than 0.5% annual probability with only a small length of raised defences and few properties at risk from a breach.

15 Lower Witham Fens Study Area

General Description of the Study Area

15.1 For the purposes of this study, the Lower Witham Fens study area has been defined as the extensive area of fenland between the Car Dyke and the River Witham or the South Forty Foot Drain (or to the District boundary where it lies to the west of these two watercourses), stretching from Washingborough in the north to the boundary with South Kesteven at Swaton in the south. The whole of the study area's western boundary is defined by the Car Dyke. Location plans of the study area are given in Figures 13.2a, b & c.

15.2 Virtually the whole of the study area consists of pump-drained fenland, within either the Witham First Drainage District or the Black Sluice Drainage District. Within the study area the boundary between the two Drainage Districts lies between the Kyme Eau (River Slea) and Billinghay Skirth. For most of its length the eastern edge of the study area is bounded by the two high-level watercourses, the Witham and the South Forty Foot. Most of the land in the study area is below flood levels in those watercourses and is thus protected from them by raised earth embankments.

15.3 A number of smaller tributary watercourses run from west to east across the study area, conveying upland water under gravity from land west of the Car Dyke to the Witham or to the South Forty Foot Drain. Like the major watercourses into which they drain, these are all high-level watercourses confined between floodbanks. From north to south they are, in sequence, Sandhill Beck, the four Delphs, Billinghay Skirth, Kyme Eau, Heckington Eau (Head Dyke), Helpringham Eau, Helpringham South Beck and Swaton Eau along the study area's southern boundary. They are all Main Rivers and are shown in Figure 13.2.

15.4 With the exception of some 'islands' of higher ground on the western fringes of the study area, notably in the Billinghay and the North and South Kyme areas, the whole of the study area lies below the 5mOD contour. Within the study area fens, land levels are generally around 2m and 3mOD but with some land in South Kyme Fen as low as 1mOD.

15.5 These high-level watercourses effectively and conveniently divide the study area into a series of eleven 'flood compartments' separated from each other by the floodbanks which follow the high-level watercourses. The flood risk implications of this configuration will be discussed later in this Section. The physical characteristics of the extensive study area will therefore be described below on the basis of the individual flood compartments.

15.6 Most of the study area is sparsely populated, although it includes two small villages, North and South Kyme, and about half a dozen smaller settlements. Despite its extensive area, approximately 175 sq.km, the total population of the study area is not more than 2,000.

<u>Washingborough Fen</u>

15.7 This is the smallest of the twelve flood compartments with a triangular shaped area of little more than 1 sq.km extending west from Sandhill Beck to a spur of higher ground where the line of the Car Dyke meets the South Delph.

15.8 Although there are few, if any, dwellings or other buildings within this flood compartment (i.e. north of the Car Dyke) the greater part of the village of Washingborough (pop.3356) lies at the foot of the slope of higher land immediately above the Car Dyke, part of which acts as a catchwater drain for surface water from the village. The flood compartment itself is drained to the South Delph by the Sandhill Beck Pumping Station.

Heighington Fen

15.9 The Heighington Fen flood compartment is a roughly triangular area, just over 6 sq.km in extent, between Sandhill Beck and Branston Delph. The whole of the area is drained to the South Delph at Heighington Fen Pumping Station.

15.10 Apart from a cluster of houses and a garden centre at the Car Dyke end of Five Mile Lane, the only other properties in the flood compartment of any significance are about half a dozen farms, most of which are situated along Middle Fen Lane.

Branston, Potterhanworth & Nocton Fens

15.11 This is one of the largest of the twelve flood compartments, nearly 24 sq.km. in extent, between Branston Delph and Nocton Delph. North of the Bardney Causeway (B1190) the area drains to the South Delph at Branston Fen Pumping Station and south of the causeway to the Lower Witham at Nocton Pumping Station. The causeway, the embanked road across the fen between Bardney Bridge and Potterhanworth Booths, would sub-divide the area into two smaller flood compartments in a major but not in an extreme flood event.

15.12 In the northern part of the area there is a handful of farms and isolated houses along the south side of Branston Delph, along Bardney Causeway, and near Bardney Lock. The hamlet of Wasps Nest lies just inside the area near the head of Nocton Delph, apart from which there are only a couple of other properties south of the Causeway. The sludge lagoons associated with the now disused Bardney Sugar Factory are situated on the west bank of the River Witham, just inside the eastern edge of the flood compartment.

Dunston & Metheringham Fens

15.13 This is a roughly rectangular flood compartment covering an area of nearly 15 sq.km. between Nocton Delph and Metheringham Delph. The area is drained to the Lower Witham at Metheringham Pumping Station.

15.14 Although there are only two or three farms and a public house in Dunston Fen, in the northern part of the area, there are two hamlets, Sots Hole and Tanvats, in the centre of Metheringham Fen as well as a number of scattered farms.

Blankney & Martin Fens

15.15 Almost square in shape, this flood compartment is situated between Metheringham Delph and Timberland Delph and covers an area of over 21 sq.km. The flood compartment is drained to the Lower Witham at Blankney Pumping Station.

15.16 The largest concentration of dwellings in this flood compartment is in the settlement of Martin Dales (population about 150) adjacent to the Witham at Kirkstead Bridge in the SE corner of the area. There are also a dozen or more farms and isolated dwellings scattered throughout this flood compartment. The B1191 road from Martin to Woodhall Spa via Kirkstead Bridge runs through the southern part of the compartment.

Timberland to Billinghay Fens

15.17 Another roughly square flood compartment, this one extends over 26.5 sq.km, situated between Timberland Delph and Billinghay Skirth. Between Timberland and Billinghay the Car Dyke runs down the eastern edge of a promontory of higher land which separates the Witham Fens from a smaller, detached basin of fenland west of the Car Dyke (not included in the study area). The flood compartment is drained to the River Witham at Timberland Pumping Station and to Billinghay Skirth at Billinghay P.S.

15.18 The majority of the village of Billinghay (pop.1808) lies at the end of the promontory of higher land, but the village also extends east of Car Dyke and into the flood compartment in the Billinghay Carrs area. A minor road runs from Tattershall Bridge to Kirkstead Bridge along the crest of the Witham flood bank on the flood compartment's eastern boundary and this road is lined at regular intervals with farms, smallholdings and dwelling houses at the base of the embankment. Elsewhere in the flood compartment there is only the usual scattering of isolated farms.

North Kyme Fen & Damford Grounds

15.19 Although this is one of the largest (28 sq.km) flood compartments in the study area, it has a relatively small length of the River Witham along its eastern boundary, little more than 3km. Most of its eastern boundary is formed by the Kyme Eau (River Slea) between South Kyme and Chapel Hill. The Billinghay Skirth forms its northern boundary. This flood compartment is divided between two IDBs. The northern part of the area (North Kyme Fen and Billinghay Dales, is drained to the lower reaches of Kyme Eau at the Witham First District IDB's Chapel Hill Pumping Station. The southern part of the area (Damford Grounds) is also drained to Kyme Eau but by the Black Sluice IDB's Damford Grounds Pumping Station.

15.20 Although as it does elsewhere, the Car Dyke forms this flood compartment's western boundary, in this area the Car Dyke runs along the western side of a ridge of marginally elevated land that extends southwards from the end of the more pronounced Billinghay promontory. This almost imperceptible silt ridge runs through the villages of North Kyme (pop.456) and South Kyme (pop.351), both of which fall within the study area, although it should be pointed out that both villages are situated above the 5mOD contour and are shown in FZ 1 on the Environment Agency's Flood Map.

15.21 Elsewhere in the flood compartment there are smaller settlements at Tattershall Bridge and Chapel Hill on the west bank of the River Witham with a total population of about 360. Development in the central part of the flood compartment is limited to scattered farms and isolated houses. The main A153 (Louth to Sleaford) road enters the flood compartment at Tattershall bridge and runs along the northern and western edges of the area, and the B1395 road along the low ridge from North to South Kyme.

South Kyme Fen

15.22 Although within the study area the eastern edge of this flood compartment follows the North Kesteven / Boston Borough boundary, the actual flood compartment is much larger and extends eastwards across Holland Fen as far as the River Witham. The 12 sq.km section within the study area comprises only the western quarter of a much larger flood compartment. The north western half of the study area flood compartment is drained into the Midfodder Dyke, a Main River tributary of Head Dyke, at Ewerby Pumping Station, whereas its south eastern half drains to South Kyme P.S. which is situated at the SE corner of the flood compartment. The Head Dyke is a tributary of the South Forty Foot Drain.

15.23 The B1395 (South Kyme to the A17) road runs from north to south across the middle of the flood compartment. That part of South Kyme village south of Kyme Eau falls within this flood compartment, apart from which development in the compartment is limited to about half a dozen scattered farms.

Heckington & Hale Fens

15.24 This is by a small margin the largest of the twelve flood compartments in the study area, with an area of 29 sq.km. The area stretches from Head Dyke in the north to Helpringham Eau in the south, a distance of nearly 7 km. The area north of the A17 road is drained to Head Dyke at Five Willow Wath by Heckington Pumping Station, although a small strip of land along the NW edge of the area is drained by Trinity College P.S. which discharges to the Head Dyke (Skerth Drain) further downstream, beyond the North Kesteven boundary. The whole of the area south of the A17 is drained by a single pumping station, Great Hale P.S., one of the Black Sluice IDB's larger installations, which discharges to the South Forty Foot Drain 1,100m upstream of Swineshead Bridge.

15.25 The flood compartment is crossed from west to east by two major transport routes, the A17 trunk road (Newark to Kings Lynn) and the Nottingham to Boston and Skegness railway. The only settlement of any note in the area is East Heckington (population 325), which straggles along the A17 road towards the District boundary. The remainder of the flood compartment is sparsely populated with a scattering of farms and isolated houses throughout the area.

Helpringham Fen

15.26 A small (6 sq.km). rectangular flood compartment, typical of those along the western side of the upper reaches of the South Forty Foot Drain, situated between Helpringham Eau and Helpringham South Beck. The whole of this flood compartment is drained to the South Forty Foot Drain at Helpringham Fen Pumping Station.

15.27 Development in this flood compartment is confined to around twenty farms and isolated houses spread out along Helpringham North and South Droves. The Lincoln to Peterborough railway line runs from NW to SE through the flood compartment, closely parallel with South Drove.

Swaton Fen

15.28 Very similar but slightly larger (6.5 sq.km.) than its northern neighbour, this flood compartment is bounded by the Helpringham South Beck and Swaton Eau. The whole of the flood compartment is drained to the South Forty Foot Drain by Swaton Pumping Station.

15.29 A virtually uninhabited flood compartment, with no more than four or five farms throughout the whole area. The main A52 (Nottingham to Skegness) road runs along the south side of Swaton Eau, just outside the area.

Hydrology of the Study Area

15.30 Although the eleven flood compartments are hydraulically independent, their hydrology is essentially very similar. There are, however, minor differences and the flood compartments can be considered in three distinct groups. Each group is described and discussed below.

15.31 The first group consists of those flood compartments for which the Car Dyke acts as a catchwater drain, effectively intercepting all the runoff and spring flow from the lower slopes of the high land (the ‘barff’) immediately to the west of the Car Dyke. Even though most of the limestone uplands are drained by the spring-fed becks which are also intercepted by the Car Dyke, a substantial amount of upland drains direct to the Car Dyke.

15.32 This group of flood compartments includes four of the more northerly compartments, from Branston, Potterhanworth & Nocton Fens south to the Timberland & Billinghay Fens. The unbroken Main River section of the Car Dyke from Branston Booths to Billinghay forms the western boundary of the four compartments. The hydrology of each of these flood compartments is discussed individually below.

15.33 Branston, Potterhanworth & Nocton Fens The Car Dyke is continuous along the western boundary of the compartment and intercepts all runoff from the uplands to the west, including three small streams in the Potterhanworth area. The discharges from Branston Fen PS to the South Delph and from Nocton Pumping Stations to the Lower Witham consist only of water derived from rain falling on the flood compartment itself.

15.34 Dunston & Metheringham Fens As before, the Car Dyke is continuous along the compartment’s western boundary and intercepts all runoff from the uplands, as well as Metheringham Beck and the substantial Dunston Beck. The discharge from Metheringham PS to the Lower Witham consists only of water derived from rain falling on the flood compartment itself.

15.35 Blankney & Martin Fens Here too the Car Dyke is continuous along the western boundary of the compartment and intercepts all runoff from the uplands to the west, including three small streams in the Potterhanworth area. The discharge to the Lower Witham from Blankney PS consists only of water derived from rain falling on the flood compartment itself.

15.36 Timberland to Billinghay Fens The Car Dyke is also continuous along the western boundary of this flood compartment but as its western boundary follows the foot of the narrow ridge from Timberland to Billinghay the volume of flood flow entering this section of the Car Dyke is minimal. Discharge from the flood compartment at Timberland PS (to the River Witham) and at Billinghay PS (to Billinghay Skirth) is limited to rain falling on the flood compartment itself.

15.37 The second group of flood compartments are those for which the Car Dyke forms a catchwater along part of the area's western boundary, but leaves a gap through which runoff from land outside the western boundary of the area can enter the pump-drained area. The hydrology of these three flood compartments is discussed individually below.

15.38 Washingborough Fen The western limit of the Main River section of Car Dyke is at Keeble Drive, close to the eastern edge of the Washingborough urban area, and there is no evidence of any local drainage discharging to the culverted head of Main River from west of this point. Apart from the recent housing development in Canterbury Drive area, which drains to the Car Dyke via a flood storage reservoir, and a tiny system serving Willow Court there are no public surface water sewerage systems in the village.

15.39 Between Keeble Drive and Ferry Lane (the western end of the flood compartment) there is no effective catchwater on the line of the Car Dyke (Fen Road, B1190) to intercept runoff from the high land south of the flood compartment and prevent it from entering the pump drained area. However, the deep railway cutting along the northern edge of the village forms an effective catchwater, diverting runoff from land south of the railway away from Washingborough, and the area of high land in Washingborough draining towards the flood compartment will be less than 1.1sq.km.

15.40 The IDB's figure for the Sandhill Beck P.S. catchment (1.7sq.km) suggests that the urban area within the catchment is no more than 0.4 sq.km, in which case the upland urban area does not contribute an excessive proportion of the water discharged to the South Delph at Sandhill Beck P.S. However the station's maximum pumping capacity of 0.50 cu.m./sq.km, compared with an average figure of 0.15 cu.m./sq.km. for land drainage pumping stations in the study area, strongly suggests that Sandhill Beck P.S. has been designed to cope with urban runoff from Washingborough village.

15.41 Heighington Fen A Main River section of Car Dyke runs NW from Fosters Bridge, intercepting flows in Heighington Beck and conveying them to the head of Sandhill Beck. Another Main River section of the Car Dyke runs SE from Poplar Bank Farm towards Branston Delph. A large stream flowing north from Potterhanworth and Branston Moor discharges to the head of Main River at Poplar Bank Farm. The Heighington Fen drainage system is connected to the Washingborough Fen system by a culvert under Sandhill Beck and some runoff from the western end of this flood compartment will be discharged at Sandhill Beck PS.

15.42 Between Poplar Bank and Fosters Bridge a detached section of the Car Dyke is part of the IDB's pumped drainage system, creating a gap in the catchwater between these two points through which runoff from the high land can flow into the flood compartment. Nevertheless, the area of high land draining direct to the fen is no more than 1.1 sq.km and hence the great majority of the water pumped to the South Delph at Heighington Fen P.S. is derived from within the flood compartment.

15.43 South Kyme Fen Although the Car Dyke is continuous along this flood compartment's western boundary, only the southern half of the Car Dyke along this boundary, here named the Midfodder Dyke, is a high-level Main River. The northern half, also called the Midfodder Dyke, is a low-level IDB drain and not in hydraulic continuity with the southern half. The IDB section of the Midfodder Drain (Car Dyke) is a part of the Ewerby P.S. catchment which includes land west of the Car Dyke. Similarly the South Kyme P.S. catchment includes a strip of land east of the District boundary. It should, however, be noted that virtually none of the water pumped from this flood compartment is runoff from high land outside the compartment as the Ewerby Catchwater, a high-level Main River, runs along almost the whole western edge of the Ewerby pumped catchment.

15.44 The third group of flood compartments consists of those flood compartments for which the Car Dyke does not provide a catchwater drain, either complete or partial. Although the Car Dyke forms the whole of the study area's western boundary, there are substantial sections of the Dyke south of Billinghay that are no longer an open watercourse but are now merely a farm ditch or a linear depression in the ground. This means that runoff from land beyond the flood compartment's western boundary drains into the flood compartment and that land is therefore part of the compartment's pump-drained catchment. The hydrology of each of these four remaining flood compartments is discussed below.

15.45 <u>North Kyme Fen & Damford Grounds</u> Between Billinghay and North Kyme the high-level Billinghay Skirth forms the flood compartment's western boundary. Between North Kyme and the Kyme Eau the Car Dyke lies to the west of the low ridge between North and South Kyme. This section of the Car Dyke is an IDB drain and part of the Witham First District IDB's extensive Farroway Pumping Station catchment. However the ridge prevents any water entering the compartment from the west, even though the Car Dyke itself does not act as a catchwater in this area. In the South Kyme area the higher land at the southern end of the flood compartment drains by gravity direct to the Kyme Eau.

15.46 This flood compartment is unusual in that it is divided between two Internal Drainage Districts, with Vacherie Lane forming the boundary between the Witham First and Black Sluice Districts. North of Vacherie Lane the larger Witham First part of the compartment is drained to Kyme Eau at Chapel Hill P.S, 0.9km upstream of the River Witham. There is also an intermediate pumping station, the North Kyme Booster P.S, which is required to drain the low land at the west end of the Chapel Hill catchment in North Kyme Fen. The smaller part of the flood compartment south of Vacherie Lane is drained to the Kyme Eau by the Black Sluice IDB's Damford Grounds P.S. which discharges into Kyme Eau 1.6km above Kyme Lower Lock.

15.47 <u>Heckington & Hale Fens</u> Between Heckington Eau and Helpringham Eau three short, isolated sections of the Car Dyke exist as IDB drains. North of the main A17 road the Heckington P.S. catchment extends west of the Car Dyke to a N-S line through the centre of Heckington village, taking in about 5sq.km of gently rising land outside the flood compartment.

15.48 South of the A17 road the Great Hale P.S. catchment also extends across the Car Dyke and as far west as the line of the B1394 road at Great Hale. Between the A17 and Great Hale Beck the pumped catchment includes about 3sq.km of almost level land west of the Car Dyke. In the Little Hale area a length of Main River, Northlands Dyke acts as a partial catchwater between Great Hale Beck and Helpringham Eau, and although some low land west of Northlands Dyke south of Little Hale drains beneath the Dyke, in this area the Great Hale P.S. catchment effectively extends only 1km west of the Car Dyke.

15.49 Great Hale Beck is an upland stream which rises on Burton Cliff, 1km west of Burton Pedwardine, at an elevation of 17mOD. Before it reaches the Car Dyke and enters the flood compartment its channel has been blocked and its flow diverted into the head of the Northlands Dyke. Hence none of this 5.3 sq.km upland catchment drains to Great Hale Pumping Station.

15.50 <u>Helpringham Fen</u> Between Helpringham Eau and Helpringham South Beck, the Main River boundaries of the flood compartment, the Car Dyke is little more than a line on the map. In theory the area of high land draining to the flood compartment will extend as far west as George Road in Helpringham. In reality there is an IDB drain, about 500m west of the Car Dyke, which runs from north to south between the two Main Rivers. Although this drain has a flapped outfall to Helpringham Eau it has no connection with Helpringham South Eau.

15.51 Although this drain may appear to be a de facto catchwater drain it only operates as such at its northern end and its southern end is connected to the Helpringham P.S. drainage system. The area of 'high land' draining into the flood compartment is therefore not just the 0.8 sq.km between Car Dyke and the IDB drain to its west. Even so, the flood flow discharged to the South Forty Foot Drain at Helpringham P.S. is largely generated from within the flood compartment.

15.52 Swaton Fen The situation in this flood compartment is similar to that in the neighbouring compartment, described above. In this case the northern two thirds of the Car Dyke along the compartment's western boundary is an IDB drain which is in hydraulic continuity through a flapped outfall at its north end with Helpringham South Beck. This drain acts as a catchwater and intercepts a small stream running east from the high land on Swaton Common. This leaves only a small area south of Parson's Drove from which runoff from west of the line of the Car Dyke drains into the flood compartment. Since this area is less than 0.5 sq.km. upland runoff from this area will have no material effect on the flood flow discharged from the flood compartment to the South Forty Foot at Swaton P.S.

15.53 Only one of the major inflows to the Car Dyke in North Kesteven is gauged; Dunston Beck at Waneham Bridge. Scopwick Beck, a limestone tributary of Billinghay Skirth via the Dorrington Dyke system, is gauged at Station Road, Scopwick, and Heighington Beck, the principal tributary of the Sandhill Beck, is gauged at Heighington.

Flood Risk within the Study Area

15.54 Virtually the whole of the Lower Witham Fens Study Area is pump drained. Because of the presence of a catchwater drain, principally the Car Dyke, or a topographical divide along the great majority of the study area's western boundary over much of the study area almost all of the water pumped from the study area will be derived from rain falling on the study area. Even in a major storm event on a saturated catchment when the runoff reaching the pumping station exceeded the pump capacity, the depth of flooding (assuming a level land surface) could only be marginally greater than the depth of the rainfall and, in practice, flooding would be extensive but very shallow.

15.55 The only flood compartments where this equivalence would not obtain would be those where there was no fully effective catchwater and the catchment of the pump-drained area extended significantly west beyond the line of the Car Dyke. These are the Washingborough Fen, South Kyme Fen, Heckington & Hale Fens and Swaton Fen flood compartments and, to a much lesser extent, the Heighington Fen and Helpringham Fen flood compartments.

15.56 It is clear that the greatest source of flood risk to this flood compartment is the network of high-level Main River watercourses that run in embanked channels along the perimeter of each flood compartment. In a major flood event in the Lower Witham catchment, the flood embankments along the River Witham or any of its high-level tributaries could be overtopped and then breached (or breached prematurely in a residual risk event) releasing a large volume of water into the flood compartment immediately behind the breach. This volume could be an order of magnitude larger than the volume of flood water arising from the type of flooding described in above.

15.57 The Environment Agency's FZs indicates that, without defences, the majority of the study area is in FZ 3, although there are considerable areas of Zone 2 and even Zone 1 land along the western edge of the study area. Approximately 80% of the study area is within FZ 3. The respective flood risk assessments for each of the eleven flood compartments in the study area are given in Table 15.1 below.

Flood Compartment	Environment Agency Flood Zone
Washingborough Fen	About 80% Zone 3, with a strip of Zone 1 land along the northern edge.
Heighington Fen	About 80% Zone 3, with Zones 1 & 2 in the Common Square / Ings Farm area.
Branston, Potterhanworth & Nocton Fens	Over 90% Zone 3, but with a large block of Zones 1 & 2 in the Woodside Farm / Langham Drain area and some Zone 1 at Branston Booths.
Dunston & Metheringham Fens	About 75% Zone 3, but with a solid block of Zone1 extending 1km or so E of the Car Dyke towards Sots Hole.
Blankney & Martin Fens	Over 95% Zone 3, with a small area of Zones 1 & 2 near Car Dyke Farm.
Timberland to Billinghay Fens	Over 95% Zone 3, with a narrow strip of Zone 1 along the Car Dyke, widening locally at Priory Hill and Gravel Hills.
North Kyme Fen & Damford Grounds	About 70% Zone 3, with a large are of Zone 1 on the marginally higher (>5mOD) land between N and S Kyme.
South Kyme Fen	Almost 100% Zone 3, but with some Zone 1 at Manor Farm and a fringe of Zone 1 along Kyme Eau in South Kyme village.
Heckington & Hale Fens	About 80% Zone 3, with a variable but broad band (up to 1km in places) of Zones 1 & 2 along the Car Dyke.
Helpringham Fen	About 50% Zone 3, with Zone 2 and some Zone 1 along the W end of North Drove and at South Drove Farm.
Swaton Fen	Only about 30% Zone 3, along Swaton Eau at Bridge End and along the South Forty Foot. Largely Zones 1 & 2.

Table 15.1 - Assessments of Flood Risk in Lower Witham Fens Flood Compartments

Actual Flood Risk

15.58 It is usual to increase the height of the river defences above the design flood level, normally by 600mm for earth defences, to give some allowance for potential bank movement, cracks in the defence and the effect of burrowing animals. This additional amount is called freeboard. Therefore the design flood level in a river can be 600mm lower that the actual defence level.

15.59 By comparing the 1:100 year flood level with the actual defence level the result of the hydraulic modelling indicates that flooding from overtopping of the defences would only occur for events in excess of 1:100 year flood event from the River Witham.

15.60 However, if the banks were to be affected by cracks, burrowing animals etc then this additional 600mm could be considered to be ineffective and should not be allowed for in the overtopping calculations. Therefore in the case of the River Witham if the level of the river banks was reduced by 600mm then overtopping would occur for events less than 1:100 years. Hence, allowing for freeboard, the River Witham’s defences do not provide a 1:100 year standard of protection to the Lower Witham Fens. Flooding would start to occur for events greater than 1:20 years.

15.61 The annual probability of flooding varies across the fens between 1% and 5%

Impact of Climate Change

15.62 Modelling is not available for the climate change implications, however as river flows increase flooding would occur more frequently than at present.

Flood Hazard

15.63 As stated above, the principal source of flood risk to the Lower Witham Fens is the River Witham itself. As the river is embanked, flooding from this source will arise when the flood bank along the river's right (west) bank is overtopped. Since overtopping of an earth embankment is assumed to cause its breaching, the large head differential between the flood level in the river and the adjacent fen will result in an equally large discharge of flood water through the breach and into the flood compartment immediately to the rear of the breach and the creation of a significant hazard zone.

15.64 The volume of water stored in the river channel between Grand Sluice and Lincoln is substantial and much of this could potentially pour through the breach, even if inflows to and outflows from the 'pond' between Grand Sluice and Lincoln are assumed to remain roughly equal. The methodologies used to determine the propagation of the flooding within the flood compartment and the width of the associated hazard zone have been described in Section 12

15.65 In theory the study area is also at risk from flooding from a breach in the floodbanks along any of the Delphs or other high level watercourses that cross the area to reach the Witham. Because timber pointing doors have been erected at the downstream ends of all these watercourses at their confluence with the Witham, a breach in these tributary floodbanks the volume of flood water entering the flood compartment will be limited to the volume stored in the much shorter and narrower length of tributary channel. This will in turn permit far less water to enter the flood compartment resulting in a much less severe flood than that which would occur from the River Witham. In addition, the inflow to Branston and Metheringham Delphs from the Car dyke can be shut off by the sluices at their upstream ends.

15.66 Estimates of the probability of less serious flooding occurring within the study area as a result of a failure of the IDB land drainage pumping stations in the area to cope with the runoff generated solely from storm rainfall over the pump-drained catchments have been given in Section 4.

Flood Hazard Maps

15.67 A flood hazard map has been produced for the study area and shown on Figure 15.2. This figure has been derived from the modelled depth and velocity results for a series of breaches where the corresponding flood hazard has been calculated. These results were then used as a guide to the possible extent of the flood hazard zones and these were used in similar locations across the study area to give an overall impression of the flood hazard within the study area.

Flood Risk to Downstream Areas

15.68 Apart from the runoff from a tiny area at South Kyme which discharges under gravity to the Kyme Eau, all flood water flowing out of the study area to exacerbate flood risk in the receiving watercourse downstream of the study area has to be pumped into the receiving watercourse. This means that the discharge from each flood compartment to the Lower Witham or two of its larger tributaries is limited to the maximum capacity of the pumping station serving the flood compartment. The maximum discharge capacity of all ten pumping stations discharging from the study area to the Lower Witham river system is 17.8 cu.m/sec and of the seven pumping stations discharging from the study area to the South Forty Foot Drain is 13.3 cu.m/sec. If these figures are adjusted for the amount of runoff pumped by these pumping stations from land outside the study area the volumes pumped from within the study area to the Lower Witham and South Forty Foot Drain reduce to 17.4 cu.m/sec and 8.1 cu.m/sec respectively.

15.69 These discharge rates are an order of magnitude smaller than the peak flood flows in the Lower Witham derived from the Lower Witham hydrologic / hydraulic model - 46 cu.m/sec at Lincoln (Stamp End), 92 cu.m/sec at Bardney Bridge and 137 cu.m/sec at Langrick Bridge in the 100-year return period flood event. It should also be borne in mind that the Environment Agency have an agreement with the Black Sluice IDB that discharges from the Board's pumping stations to the South Forty Foot will be halted if flood levels in the Drain give cause for concern.

15.70 It is clear from the above that, provided the capacities of the IDB pumping stations serving the study area are not significantly increased, flood flows from the study area do not cause a significant increase in flood risk to land and property downstream.

15.71 Since any large scale new development within the study area will almost inevitably take place on ‘greenfield’ land in pump-drained catchments, it follows that the additional surface water runoff generated by such developments will be discharged into the arterial drainage systems, thereby increasing the demands on the pumped-drainage infrastructure at critical periods and diminishing the current standards of flood protection within those catchments. It is therefore essential that the design of the new drainage systems associated with any greenfield development in the study area should incorporate runoff retention and flow retarding features.

Conclusion

15.72 Within FZ 3 and 2 the actual level of flood risk, allowing for 600mm of freeboard, varies between 5% and 1% annual probability and the sequential approach to land allocation, and for planning applications, should be applied in this study area.

15.73 The flood hazard zones show that for a distance of some hundred meters from the raised defences a breach would prove dangerous to all and any further development in this area should be avoided. A large portion of the Fen is shown to have a danger to most rating and any development in this area would need to be informed by a detailed flood risk assessment identifying how the development could be made safe

15.74 Detailed site specific Flood Risk Assessments will be required to determine the actual level of flood risk for specific locations. Land at the least risk of actual flooding should be developed in preference to higher flood risk areas.

16 Sequential Approach

16.1 A sequential risk-based approach to determining the suitability of land for development in flood risk areas is central to the policy statement of PPS 25 and should be applied at all levels of the planning process.

16.2 Local authorities should apply the sequential approach as part of the identification of land for development in areas at risk of flooding.

16.3 This approach is a simple decision making tool designed to ensure that areas at little or no risk of flooding are developed in preference to areas at higher risk. LPAs should make the most appropriate use of land to minimise flood risk, substituting land uses so that the most vulnerable development is located in the lowest risk areas. They should also make the most of opportunities to reduce flood risk, e.g. creating flood storage and flood pathways when looking at large-scale development.

Sequential Test

16.4 The level 1 SFRA has enabled the study to use the sequential approach by applying the Sequential Test to First and Second Tier settlements as identified in the Local Plan, which are the most likely to be subject to further housing allocations.

16.5 The Sequential Test has indicated the possibility of further development in areas of FZs 2 and 3 in the part of the Western Growth Corridor, which lies in Skellingthorpe Parish,(but not including the existing built up area of the village), North Hykeham and Sleaford. The Lower Witham Fens, whilst not being subject to major development in the future, is almost entirely shown to be at high flood risk.

Exception Test

16.6 In order to inform the Exception Test in these areas a more detailed Level 2 SFRA has been identified. This detailed SFRA has defined the actual flood risk within the FZs and, if development is identified, this will also enable the sequential approach to be applied to those areas.

16.7 As part of this study a Level 2 SFRA has only been undertaken for Sleaford and the Lower Witham Fens which has identified how the sequential approach could be undertaken.

16.8 If the Exception Test is passed and further development is to be allocated in FZs 2 and 3 then a sequential approach within the two study areas should be used as follows.

<u>Sleaford</u>

16.9 Significant parts of the Sleaford study area are shown to be in FZ 1, i.e. little or no flood risk. Further development should take place in FZ 1 and, where there is no available land in FZ 1, development should then be directed to FZ 2. Only where this is not possible should development be considered in FZ 3, and where necessary the Exception Test will need to be applied.

16.10 The detailed assessment of actual flood risk has indicated that these areas are protected from flooding for events <1% and, if no alternative sites in FZ 1 are available, then this area is at low risk of flooding and could be made available for further development.

16.11 Although sites may have a standard of protection from flooding of <1% they may still be subject to flooding from a failure or overtopping of the defences. However, for Sleaford it has been found that there is an insignificant risk from breaching of the defences and therefore this is not considered to be an issue.

Lower Witham Fens

16.12 Approximately 80% of the study area is shown to be in FZ 3 and 2 and most of the study area is sparsely populated, although it includes two small villages, North and South Kyme, and about half a dozen smaller settlements. Despite its extensive area, approximately 175 sq.km, the total population of the study area is not more than 2,000. It is therefore unlikely that any major development will take place but it is still necessary to apply the sequential approach to individual planning applications, so that development takes place in the lowest flood risk areas and is made safe, particularly as in this area a failure of the raised defences could be dangerous

16.13 By using actual flood risk as described in sections 14 and 15 as the criterion it should be possible to locate new development in the lower flood risk areas.

16.14 Any new development should be avoided in the flood hazard zone of “Danger to All” and should only be allowed in “Danger to Most” if suitable mitigation measures can be design as part of a detailed site specific flood risk assessment.

16.15 The action plan for the River Witham CFMP includes a recommendation that a detailed strategy is undertaken for the Lincolnshire Fens, which include this study area, to consider how flood risk will be managed in the future. NKDC will need to work with the Environment Agency on this project as areas for flood storage may be being considered which would be in the risk to all flood hazard zone.

17 Guidance For Planners and Developers

17.1 The purpose of this section is to provide guidance to planners and developers on how to manage flood risk through the design of the development.

17.2 These mitigation measures should only be considered after the sequential approach has been applied to development proposals and the location of development should be in areas of lowest flood risk. Only when it has been established that there are no suitable alternative options in lower risk areas should design solutions be considered to exceptionally allow development to proceed in flood risk areas. Where design solutions are considered appropriate, they need to meet the policy objectives of PPS25 that it must be safe without increasing flood risk elsewhere and where possible reduce flood risk overall.

17.3 A range of measures can be used to manage flood risk at development sites. NKDC will use the information in this SFRA to establish the design criteria developers will need to meet through LDD policy.

17.4 Developers should discuss proposals at the earliest possible stage with the LPA, Environment Agency and other key stakeholders so that design issues can be agreed and innovative design solutions considered if necessary.

Development Sites

17.5 A number of measures which can be used to manage flood risk at new development sites are discussed below.

17.6 Appendix A3 in CIRIA (2004) Report C624 *Development and flood risk – guidance for the construction industry* provides further details of mitigation measures for flood risk management.

17.7 Important flood risk factors to consider which will influence the design of new developments are:

- flood mechanism (how the site would flood);
- predicted flood level;
- duration;
- frequency;
- velocity of flood water;
- depth; and
- amount of warning time of flooding.

Flood Avoidance

17.8 The best way to avoid flood risk is to locate the development outside areas of flood risk i.e. FZ 1.

Site Layout

17.9 Where the Sequential Test shows that there are no suitable available alternative sites in lower flood risk areas and development is required, the sequential approach should be applied within the development site to locate the most vulnerable elements of a development in the lowest risk areas. Residential areas may contain a variety of land uses, including dwellings, vehicle and pedestrian access, parking areas, shops, schools and other community facilities. Layout should be designed so that the most vulnerable uses are restricted to higher ground at lower risk of flooding, with more flood-compatible development (parking, open space etc.) in the highest risk areas.

17.10 In designing site layout the use of low-lying ground in waterside areas for recreation, amenity and environmental purposes can provide important flood conveyance and storage as well as providing connected green spaces with consequent social and environmental benefits This green infrastructure has the potential to raise the profile and profitability of a development and contribute to other sustainability objectives.

17.11 Landscaping of public access areas subject to flooding should allow for easy access to higher land as flood waters rise and avoid local features that could become isolated islands. Fences, hedges and walls should be designed so that they do not cause obstructions to escape routes. Any essential structures, such as shelters and seats, should be designed to be flood resilient and firmly attached to the ground.

17.12 The planning permission should make provision for future management of such areas through planning conditions or Section 106 agreements, with particular regard to safety signing, permitted and prohibited structures and the management of vegetation.

17.13 PPS25 requires safe access and escape to be available to and from new developments in flood risk areas.

17.14 Where large areas are identified for development a more detailed site specific FRA should identify key flow routes which can be planned on a strategic basis. This facilitates linking of surface water drainage systems and making allowance for overloading of piped systems. It also enables these to be safeguarded for the future by protecting them from development and other obstruction.

17.15 Development proposals should include surface water drainage systems designed to incorporate key overland flow routes.

17.16 Car parking may be appropriate in areas subject to flooding, provided flood warning is available and signs are in place. Car parks should ideally not be subject to flood depths in excess of 300mm depth since vehicles can be moved by water of this depth Car parks located in areas that flood to greater depths should be designed to prevent vehicles floating out of the car park

17.17 When considering car parking within flood risk areas, the ability of people to move their cars within the flood warning time should be considered. Long-term and residential car parking is unlikely to be acceptable in areas which regularly flood to a significant depth, due to the risk of car owners being away from the area and being unable to move their cars when a flood occurs. Like other forms of development, flood risk should be avoided if possible. If this is not feasible, the FRA should detail how the design makes the car park safe.

Raising Floor Levels

17.18 Development in the Lower Witham Fens will be small scale and it is likely that avoidance and site layout are not possible. In this instance raising floor levels above the flood level is a possible option to manage flood risk to new developments. Raised floor levels can be used both as a primary flood risk management method and also to manage the residual flood risk from a failure of the defence, but safe access must be provided.

17.19 Provided there is adequate flood warning available it may be reasonable to design development with parking or other flood-compatible uses at ground level and residential or other people-intensive use above the flood level. Where developments incorporate open space beneath the occupied level, measures such as legal agreements need to be in place to prevent inappropriate use or alteration of the ground floor that would impede flood conveyance or reduce flood storage.

17.20 Single-storey residential development is generally more vulnerable to flood damage and occupants do not have the opportunity to retreat to higher floor levels. Safe refuge above flood level should be designed into new developments within flood risk zones.

Modification of Ground Levels

17.21 Risk to the development may be reduced by raising land by civil engineering operations above the level of flood risk, or to reduce the depth of flood water in extreme conditions to acceptable levels. This will need to be considered early in the design stage. Care is needed to avoid the formation of islands which would become isolated in flood conditions and to ensure there is safe access and egress. Land raising may not be viable if existing buildings or other features at existing ground level need to be retained. Any proposal to modify ground levels will have to demonstrate in the FRA that there is no increase in flood risk to the development itself, or to any existing buildings which are known to, or are likely to flood. The calculation of the impacts on floodplain storage volumes should be included in the FRA, which should show how the overall design mitigates any impacts.

17.22 Unless the development is located in an area which is subject to tidal flooding and which serves no conveyance function, land raising must be accompanied by compensatory provision of flood storage either on site or in the vicinity of the site

Development Behind Floodwalls and Embankments

17.23 Wherever possible the construction of new defences to enable development to take place should be avoided, so that residual risks are not created. Developers proposing this solution will need to show that other options, such as upstream storage and attenuation of flows, have been considered, justify why they are not feasible and that the proposal is compatible with the long-term plans for general flood risk management in the area, such as CFMPs, SMPs and IDB management.

Upstream Flood Storage

17.24 The provision of upstream flood storage, either on or off the line of a river or watercourse may be an effective way to manage water levels at a development site. Such upstream storage areas can consist of flood storage reservoirs, controlled washlands or less formal (and less hydraulically efficient) flood storage areas such as wetlands. Such facilities also have the potential to provide additional habitat and amenity uses.

Building Design

17.25 The final step is to mitigate through building design. This represents the least preferred option for new development as although buildings can be designed for reducing the impacts of flooding, hazards still remain, particularly for access and utility supply.

17.26 Communities and Local Government have published guidance on *Improving the Flood Performance of New Buildings: flood resilient construction* (2007). This provides detailed guidance on approaches to building design regarding flood risk.

17.27 Buildings should be designed to withstand the effects of flooding. In areas of high velocity water, buildings should be structurally designed to withstand the expected water pressures, potential debris impacts and erosion which may occur during a flood event. Particular care should be taken in the design of any building located in the Danger To All flood hazard zone as shown on Figure 15.1.

Flood Resistance and Resilience

17.28 Since any flood management measures only manage the risk of flooding rather than remove it, flood resistance and flood resilience may need to be incorporated into the design of buildings and other infrastructure behind flood defence systems. Flood resistance, or dry proofing, stops water entering a building. Flood resilience, or wet proofing, will accept that water will enter the building but through careful design will minimise damage and allow the re-occupancy of the building quickly.

17.29 Resistance and resilience measures are unlikely to be suitable as the only mitigation measure to manage flood risk, but they may be suitable in some circumstances, such as:

- water-compatible and less vulnerable uses where temporary disruption is acceptable and an appropriate flood warning is provided.
- in some instances where the use of an existing building is to be changed and it can be demonstrated that no other measure is practicable.
- as a measure to manage residual flood risk.
- developments which are designed with raised floor levels should be constructed using flood resilient methods to above the predictive extreme flood level.

17.30 In order to decide which resilience measures would be effective, it is necessary to know the potential depth and duration of flooding that is likely to occur. *Improving the flood performance of new buildings: flood resilient construction* (Communities and Local Government, 2007) gives guidance on flood proofing measures that are applicable to different ranges of flood depths outside a building, i.e. :

- less than 0.3m
- above 0.3m but less than 0.6m
- above 0.6m.

17.31 This is because the pressure exerted by greater depths of water, or where it is flooded for a long time, can result in the failure of flood resistant construction, either by seepage of water through walls and barriers, or causing structural damage. Flood resistance becomes more practicable for shallower water, and buildings affected by deep water will need to consider resilience.

17.32 Flood resistance measures should be used with caution. To work successfully, people must have the knowledge and ability to ensure the flood resistance elements (such as barriers, drop in boards, or wall mounted plates to cover air bricks) are put in place and maintained in a good state. Warning systems will be needed to ensure that adequate time is allowed to deploy any resistance measure. This approach would not be suitable in areas of surface water flooding which can occur very quickly. The impact of the loss of flood storage, including the requirement for the provision of compensatory flood storage, should be considered if it is intended that a proposed development should use flood resistance methods to prevent flooding of a building.

17.33 Flood repairable construction is important to avoid people being excluded from their homes for long periods after flooding has occurred, and the stress and potential health problems this can cause. (CIRIA guidance *Repairing buildings following flooding*).

18 Sustainable Drainage Systems

18.1 Traditional drainage is designed to move rainwater as rapidly as possible from the point at which it has fallen to a discharge point, either a watercourse or soakaway. This approach has a number of potentially harmful effects:

- Runoff from hard paving and roofing can increase the risk of flooding downstream, as well as causing sudden rises in water levels and flow rates in watercourses.
- Surface water runoff can contain contaminants such as oil, organic matter and toxic metals. Although often at low levels, cumulatively they can result in poor water quality in rivers and groundwater, affecting biodiversity, amenity value and potential water abstraction. After heavy rain, the first flush is often highly polluting.
- By diverting rainfall to piped systems, water is stopped from soaking into the ground, depleting ground water and reducing flows in watercourses in dry weather

18.2 Sustainable Drainage Systems (SUDS) include tried-and-tested techniques that are already being implemented on a range of projects and they incorporate cost-effective techniques that are applicable to a wide range of schemes.

18.3 Planning Policy Statement 25 emphasises the role of SUDS and introduces a general presumption that they will be used. SUDS will probably feature increasingly in such guidance documents as they are revised.

18.4 As with other key considerations in the planning process incorporating SUDS needs to be considered early in the site evaluation and planning process, as well as at the detailed design stage. The use of Drainage Impact Assessments has been piloted in Aberdeen and Aberdeenshire in Scotland.

18.5 North Kesteven District Council expect planning applications, whether outline or detailed, to demonstrate how a more sustainable approach to drainage is to be incorporated into development proposals, and for detailed design information to be submitted at the appropriate stage and may use planning conditions to secure the implementation of SUDS.

18.6 Building Regulations on Drainage and Waste Disposal for England have been modified to introduce a surface water drainage hierarchy, with infiltration on site as the preferred disposal option, followed by discharge to watercourse and then connection to a sewer.

18.7 The SUDS approach to drainage incorporates a wide variety of techniques and as a result, there is no one correct drainage solution for a site. In most cases, a combination of techniques, using the Management Train principle, will be required.

18.8 The elements of the Management Train are outlined below.

Source Control

Green Roofs and Rainwater Re-use

18.9 Green roofs can improve water quality and reduce the peak flow and the total volume discharged from a roof.

18.10 In addition, they can enhance insulation and increase the lifespan of the roof. Rainwater reuse (or harvesting) involves the collection and storage of rainwater on site and its use as a substitute for mains water, for example in watering gardens or for flushing toilets.

Permeable Pavements

18.11 The need for surface water drains and off-site sewers can be reduced or eliminated where runoff is encouraged to permeate through a porous pavement, such as permeable concrete blocks, crushed stone or porous asphalt.

18.12 Depending on the ground conditions, the water may infiltrate directly into the subsoil or be stored in an underground reservoir (for example, a crushed stone layer) before slowly soaking into the ground. If infiltration is not possible or appropriate (for example, because of ground contamination), an impermeable membrane can be used with an overflow to keep the pavement free from water in all conditions. Pollutant removal occurs either within the surfacing or sub-base material itself, or by the filtering action of the reservoir or subsoil.

Infiltration Techniques

Infiltration Trenches

18.13 An infiltration trench is a shallow, excavated trench that has been filled with stone to create an underground reservoir.

18.14 Stormwater entering the trench is gradually infiltrated into the ground. Their longevity can be enhanced by providing pre-treatment of the stormwater using a filter strip, gully or sump pit to remove excessive solids.

Filter Drains

18.15 Filter drains are widely used by highway authorities for draining roads.

18.16 They are similar structures through which a perforated pipe runs. This facilitates the storage, filtering and some infiltration of water passing from the source to the discharge point. Pollutants are removed by absorption, filtering and microbial decomposition in the surrounding soil. Systems can be designed to successfully incorporate both infiltration and filter systems.

Swales and Basins

18.17 These can be created as features within the landscaped areas of the site, or they can be incorporated into ornamental, amenity and screen-planted areas where they would be looked after as part of the normal maintenance contract. Swales and basins are often installed as part of a drainage network connecting to a pond or wetland, prior to discharge to a natural watercourse.

Swales

18.18 Swales are grassed depressions which lead surface water overland from the drained surface to a storage or discharge system, typically using the green space of a roadside margin.

18.19 They may be used to replace conventional roadside kerbs, saving construction and maintenance costs. Compared to a conventional ditch, a swale is shallow and relatively wide, providing temporary storage, conveyance, treatment and the possibility of infiltration under suitable conditions.

Basins

18.20 A basin is designed to hold back storm runoff for a few hours and to allow the settlement of solids.

18.21 They are dry outside of storm periods. They provide temporary storage for storm water, reduce peak flows to receiving waters, facilitate the filtration of pollutants (deposited and incorporated into the substrate) and encourage microbial decomposition, as well as allowing water infiltration directly into the ground.

Ponds and Wetlands

18.22 Ponds or wetlands can be designed to accommodate considerable variations in water levels during storms, thereby enhancing flood-storage capacity.

18.23 Although these can be designed as wet or dry ponds, or wetlands, they are most likely to contribute to visual amenity and biodiversity where they include a permanent water body. By allowing adequate detention time, the level of solids removal can be significant. The algae and plants of wetlands provide a particularly good level of filtering and nutrient removal. Ponds and wetlands can be fed by swales, filter drains or piped systems. The use of inlet and outlet sumps enhances performance by trapping silt and preventing clogging of the outlet. Removal of collected sediment from the inlet sump may be needed, although typically this is unlikely to be more than once every seven years.

Geology

18.24 The effectiveness and suitability of some of the above SUDS techniques will depend on the ground conditions into which the water permeates. The ground is made up of different layers and the material within each layer will determine how groundwater flows through the catchment. The bedrock is made up of compacted rocks. Above this are less compact rocks, known as drift geology. The top layer is soil. Drift deposits are not always present and when this is the case, the soil is positioned directly on top of the solid geology.

18.25 Some types of solid geology can be more permeable than others (e.g. sandstone compared to clay). Permeable bedrock absorbs and stores water, which reduces runoff and can result in rivers taking longer to respond to rainfall events. This reduces peak flows in rivers, and reduces the flood risk as a result.

18.26 Where no storage is available, in the less permeable bedrock, less rainfall is absorbed and it can run through the shallow soil strata to the nearest watercourse. The same applies to drift geology (e.g. peat is highly permeable).

18.27 For the district of North Kesteven the solid geology consists of mudstone (west of Lincoln) and clay (east of Lincoln), with a ridge of limestone running north-south through Lincoln.

18.28 The mudstone and clay areas are not very permeable, and as a result cannot store large quantities of water and are not suited to the infiltration methods. Consequently these areas will generate runoff and lead to high river flows which can pose a flood risk. The limestone area is much more permeable than the mudstone and clay and can absorb and store rainwater, thereby reducing the flood risk.

Adoption and Maintenance

18.29 For SUDS to provide consistent and effective long-term attenuation of runoff from a development, they have to be maintained in an efficient condition for the life of the development. This may involve the control of weed growth in ponds and lagoons, the frequent removal of debris, both natural and man-made, from watercourses and weedscreens, the clearance of blockages, sometimes at short notice, from pipes and culverts, and the repair of malicious damage and vandalism. A routine inspection regime is essential to ensure that any such problems are identified and dealt with in a timely manner.

18.30 If widespread urban development takes place in the Witham catchment upstream of North Kesteven (i.e. in South Kesteven and West Lindsey) it could have a material effect on fluvial flood risk in North Kesteven. Only modest housing growth is proposed for West Lindsey, much of which will probably be outside the Witham catchment, but runoff from the substantial urban growth proposed for South Kesteven could have a significant effect in the Witham catchment if concentrated in Grantham, which has been identified in the Regional Plan as a sub-regional centre, unless SUDS are fully incorporated into the surface water drainage systems of all new development in that location.

18.31 Following the publication of the Pitt Review, the Government made a commitment to resolve some of the barriers to SUDS through the draft Floods and water Bill. This included an announcement that Upper Tier Local Authorities would be given a duty to adopt SUDS drainage systems constructed for new developments. This is an important commitment which will go some way to reducing the impact of new developments on surface water quality and flood risk.

- This page left blank intentionally -

19 Conclusions

Level 1 SFRA

19.1 The original North Kesteven Strategic Flood Risk Assessment (SFRA) was published in September 2002 and has subsequently been used to inform the Council's planning policies.

19.2 North Kesteven District Council has commissioned a revised and updated SFRA which will be used to inform the Core Strategy of the District Council's Local Development Framework.

19.3 The SFRA is at the core of the PPS25 approach. It provides the essential information on flood risk, taking climate change into account that allows the LPA to understand the risk across its area so that the Sequential Test can be properly applied.

Sequential Test

19.4 This study has applied the Sequential Test to the First and Second Tier settlements in the Local Plan by using the Environment Agency FZs.

19.5 The majority of new development will be located in FZ 1.

19.6 The results of the Sequential Test indicated that for Sleaford some housing development may be required in FZ 3 and for the Lower Witham Fens there is an extensive area of FZ 3. Therefore, to inform the Exception Test it was necessary to undertake further, more detailed Level 2 SFRAs for these areas.

19.7 An area of Skellingthorpe Parish, which is part of the Western Growth Corridor and is outside of the current built up area of the village, and an area of North Hykeham to the east of the current built up area both lie within FZ 3 and could be subject to future development. These two locations have been considered in the Lincoln Policy Area Level 2 SFRA.

Climate Change

19.8 Climate change is expected to increase river flows and this may have an impact on the extent of the current FZs.

19.9 When considering the availability of land currently shown to be within FZ 2 NKDC should consider that the land has the potential to be within FZ 3 in 100 years time and may require further detailed consideration of the impact of climate change before making a decision on the allocation of the land for development.

19.10 NKDC should note that any proposed land allocation currently shown to be within FZ 1, and adjacent to the extent of the current FZ 2, will have the potential to be within FZ 2 in the future.

Level 2 SFRA

19.11 For this SFRA Sleaford and the Lower Witham Fens have been subjected to a level 2 SFRA.

19.12 The part of Skellingthorpe Parish which is part of the Western Growth Corridor and an area of North Hykeham to the east of the current built up area have been considered in the Lincoln Policy Area Level 2 SFRA

Sleaford

19.13 Whilst parts of this study area are shown to be in FZ 3 and 2 the defences that exist reduce the risk of flooding to less than 1% annual probability.

19.14 If any of the raised flood defences failed during a major (100 or 200-year) flood event, the only properties at risk of flooding would be houses at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated.

19.15 Climate change is expected to increase river flows but this is not expected to have a significant effect on the actual flood risk to Sleaford.

Lower Witham Fens

19.16 Virtually the whole of the study area consists of pump-drained fenland. For most of its length the eastern edge of the study area is bounded by the two high-level watercourses, the Witham and the South Forty Foot. Most of the land in the study area is below flood levels in those watercourses and is thus protected from them by raised earth embankments.

19.17 Most of the study area is sparsely populated, although it includes two small villages, North and South Kyme, and about half a dozen smaller settlements. Despite its extensive area, approximately 175 sq.km, the total population of the study area is not more than 2,000.

19.18 Most of the study area is shown to be within FZ 3 with defences reducing the probability of flooding, however failure of these defence could result in loss of life.

19.19 Climate change is expected to increase river flows and this could have a significant effect on the actual flood risk in the Lower Witham Fens and increase the probability of breaching the defences.

Sequential Approach

19.20 Significant parts of the Sleaford study area are shown to be in FZ 1, i.e. little or no flood risk and these areas should be developed in preference to other, higher flood risk areas. Sleaford is likely to be the focus for significant growth in the future.

19.21 Further development should take place in FZ 1 and only be identified to take place in FZs 3 and 2 following the successful application of the Exception Test. The detailed assessment of actual flood risk has indicated that these areas are protected from flooding for events <1% and, if no alternative sites in FZ 1 are available, then this area is at low risk of flooding and could be made available for further development.

19.22 Although sites may have a standard of protection from flooding of <1% they may still be subject to flooding from a failure or overtopping of the defences. However, for Sleaford it has been found that there is an insignificant risk from breaching of the defences and therefore this is not considered to be an issue.

19.23 For the areas of the Lower Witham fens within FZ 3 and 2 the actual level of flood risk varies and it is necessary to apply the sequential approach to individual planning applications, so that development takes place in the lowest flood risk areas and is made safe, particularly as in this area a failure of the raised defences could be dangerous

19.24 The flood hazard zones show that for a distance of some hundred meters from the raised defences a breach would prove dangerous to all and any further development in this area should be avoided. A large portion of the fen is shown to have a ‘danger to most’ rating and any development in this area would need to be informed by a detailed flood risk assessment identifying how the development could be made safe.

Guidance For Planners and Developers

19.25 Where design solutions are considered appropriate, they need to meet the policy objectives of PPS25 that it must be safe without increasing flood risk elsewhere and where possible reduce flood risk overall.

19.26 A range of measures can be used to manage flood risk at development sites. NKDC will use the information in this SFRA to establish the design criteria developers will need to meet through LDD policy.

19.27 Developers should discuss proposals at the earliest possible stage with the LPA, Environment Agency and other key stakeholders so that design issues can be agreed and innovative design solutions considered if necessary.

Sustainable Drainage Systems

19.28 North Kesteven District Council expect planning applications, whether outline or detailed, to demonstrate how a more sustainable approach to drainage is to be incorporated into development proposals, and for detailed design information to be submitted at the appropriate stage and may use planning conditions to secure the implementation of SUDS.

- This page left blank intentionally -

20 Recommendations

20.1 In accordance with the findings of this study and the conclusions reached in Section 19 of this Report the following recommendations are made, that North Kesteven District Council :-

- Use this Strategic Flood Risk Assessment to inform the Core Strategy of the District Council’s Local Development Framework.
- Continue to apply the Sequential Test using the Environment Agency FZs
- Undertake further supporting studies as necessary based on the information on the Environment Agency Areas Susceptible to Surface Water Flooding maps.
- Consider adopting a precautionary approach when looking for further development sites and consider the effect of climate change on the extent of FZs.
- Within Sleaford ensure that further development takes place in FZ 1 and, where there is no available land in FZ 1, directed development to FZ 2. Only where this is not possible should development be considered in FZ 3, and where necessary the Exception Test will be applied.
- Note that the result of detailed hydraulic modelling indicates that flooding would not occur in Sleaford for the 1:100 or 1:200 year events, so the probability of flooding is <0.5%.
- Note that if any of the raised flood defences failed during a major flood event, the only properties at risk of flooding would be houses at the west end of Electric Station Road and four commercial properties south of East Gate. The strip of low-lying land between the River Slea and the Old River Slea would also be inundated.
- Note that the detailed assessment of actual flood risk has indicated that these areas are protected from flooding for events <1% and, if no alternative sites in FZ 1 are available, then this area is at low risk of flooding and could be made available for further development and it has been found that there is an insignificant risk from breaching of the defences in Sleaford.
- Within the Lower Witham Fens ensure development proposals are informed by a detailed flood risk assessment which considers the effect of climate change on the level of flood risk.
- Within the Lower Witham Fens discourage any development in the “Danger for All” flood hazard rating.
- Within the Lower Witham Fens ensure that any development in the “Danger to Most” flood hazard rating is informed by a detailed flood risk assessment identifying how the development could be made safe.
- Will establish the design criteria developers will need to meet through LDD policy.
- Encourage developers to discuss proposals at the earliest possible stage with themselves, the Environment Agency and other key stakeholders so that design issues can be agreed and innovative design solutions considered.
- Require a FRA for all planning applications in accordance with PPS25 and the Practice Guide
- Use planning conditions to secure the implementation of SUDS
- Consider using the following draft policies within their LDD:

Proposed Policy 1

For the following settlements all future major development will only be allowed in FZ 1. Whilst it is recognised that some of the existing settlement area is within FZs 3 and 2 there is sufficient capacity to identify future major development areas outside of the FZs, this will reduce the future flood risk.

Where there is a perceived need to redevelop brown field sites in the FZs then options to restore these to natural floodplain and green infrastructure must fully explored, so that the level of existing flood risk can be reduced, before other alternatives are considered.

Proposed Policy 2

For the following settlements all future major development should be located in FZ 1. However it is recognised that, due to the extent of FZs 3 and 2, there may be a need to identify future major development areas within the FZs and this must be located in areas of reduced flood risk.

Where it is necessary, following application of the Sequential Approach, to locate new development in FZs 2 and 3, such development should be focused within areas where:

- The preferred policy option in the relevant CFMP is a Policy 4 or 5 over the lifetime of the development.
- The standard of protection afforded by the existing defences is compatible with the land use type proposed.
- Application of the sequential approach using detailed site specific Flood Risk Assessments has been used to identify the areas within the zone that are at least risk, and
- Flood forecasting and warning systems, as well as flooding emergency response procedures, are well-developed.

Where there is a perceived need to redevelop brown field sites in the FZs then options to restore these to natural floodplain and green infrastructure must fully explored, so that the level of existing flood risk can be reduced, before other alternatives are considered.

Appendix A - Sources of Flooding

Sources of Flooding

Upper River Witham

The River Witham rises in the limestone uplands of southwest Lincolnshire south of Grantham and enters North Kesteven near Beckingham where its catchment area is already 332 sq.km. It then continues northwards through the Trent plain towards Lincoln via Stapleford and Bassingham. About 2.5km downstream of Aubourn the Witham is joined by the River Brant. Between Aubourn and Lincoln the Witham is slightly embanked and the adjacent floodplain in the South Hykeham area is pump drained. Its total catchment area when it leaves the District at North Hykeham is 559 sq.km.

The River Brant rises in South Kesteven between Marston and Claypole and flowing north, parallel with the Upper Witham, enters North Kesteven near Stragglethorpe. It then continues north along the eastern edge of the Trent plain, the eastern boundary of its catchment being the crest of the scarp slope of the Lincoln Edge. By the time it meets the Witham near Aubourn its catchment area has increased from 60 sq.km at Brant Broughton to 147 sq.km.

The Upper Witham catchment in North Kesteven is a gently undulating and predominantly arable agricultural area between the Trent and the Lincoln Edge. Within this area both the Upper Witham and the Brant have relatively extensive floodplains.

In the late 1980s a large flood storage area was created in the floodplain at the confluence of the Witham and the Brant in the Aubourn / South Hykeham area as part of the Lincoln Flood Alleviation Scheme.

Lower River Witham

The Upper Witham meets the Fossdyke Canal at the Brayford Pool in Lincoln. The Lower Witham emerges from the east end of Brayford Pool and passes along a narrow and constricted channel through the centre of Lincoln. The inadequacy of this waterway has long been recognised and in the distant past a flood relief channel, the Sincil Dyke, was excavated. This leaves the Upper Witham at Boultham, 1.8km upstream of Lincoln city centre, and follows a parallel but lower-level course through the city to the east and south of the river. Originally the Sincil Dyke rejoined the Witham at Stamp End on the eastern edge of the city but in the late C18 it was extended on a closely parallel route to rejoin the river upstream of Bardney. This downstream extension of the Sincil Dyke is known as the South Delph.

Discharge of flow from the Upper Witham to the head of the Sincil Dyke is controlled by Bargate Sluice. Flows (and navigation levels) in the Witham itself through Lincoln are controlled by sluices at Stamp End. Where the Witham re-enters North Kesteven near Washingborough to form the District’s northern and eastern boundaries its catchment area has increased to 821 sq.km.

Downstream of Lincoln the Lower Witham, the main higher level navigation channel, and the South Delph, the lower level flood relief channel, run in parallel to Bardney. At Fiskerton Sluice flood flows in the main higher level channel can be discharged to the Old River Witham, an embanked channel that follows the original line of the Witham on a loop to the north, ensuring that no substantial flows pass down the navigation channel to Bardney Lock. The land within the loop is known as Branston Island and is used as a flood storage area. Its operation will be described in more detail later in Section 5.

Just downstream of Bardney Lock the Old River Witham and South Delph recombine with the navigation channel to form the single embanked channel of the Lower Witham from there to the river's tidal limit at Grand Sluice, Boston. Grand Sluice controls water and flood levels not only in the Witham between Boston and Bardney but also the water levels in the South Delph and the Old River Witham.

The course of the River Witham runs down the east side of its floodplain between Bardney and Dogdyke, leaving an extensive area of fenland on the Kesteven side of the river, between the river and the foot of the limestone ridge to the west. A series of four high-level embanked channels - the Branston, Nocton, Metheringham and Timberland Delphs - run from west to east across these fens connecting the Car Dyke (see below) with the Lower Witham.

These Delphs are all Main Rivers but carry relatively modest flows. Metheringham Delph has not been used as a drainage channel for the past twenty years and is maintained solely as a linear wetland for its ecological importance. In more recent years Branston Delph has also been maintained as a linear wetland although it is still used to convey limited discharges from the Car Dyke to the Lower Witham in the winter months.

The Delphs were all originally equipped with timber pointing doors (mitre gates) at their downstream ends to prevent backflow from the Witham, thereby minimising the volume of water that could escape from the river in the event of a breach in any of the flood banks along the Delphs. Branston Delph now has a flap valve at its downstream end and the outfall from Metheringham Delph to the Witham is controlled by penstocks.

By the time it reaches Kirkstead Bridge the Witham's catchment area has increased to 1497 sq.km and where the river leaves North Kesteven at Chapel Hill its catchment area, which now includes its two major tributaries, the Rivers Bain and Slea, is 2041 sq.km.

Apart from the Delphs, the only right bank tributary of the Witham of any consequence between Lincoln and Billinghay Skirth (see below) is the Heighington Beck. This spring-fed limestone stream with a 26 sq.km catchment would originally have been intercepted by the Car Dyke (see below) but it now discharges to the South Delph along Sandhill Beck, a short length of embanked channel across the narrow strip of fen north of Washingborough.

<u>Billinghay Skirth</u>

From Metheringham a narrowing tongue of marginally higher land extends southwards to Billinghay, leaving a detached basin of fenland between this tongue of land and the foot of the limestone ridge to the west. This basin and the dip slope of the limestone ridge behind it are drained by Billinghay Skirth.

The two principal streams draining the dip slope west of Billinghay are Scopwick Beck (27 sq km) and Springwell Brook (29 sq.km). These two streams are conveyed across the fenland basin in small embanked channels which, together with pump-drained inputs from IDB catchments within the basin, converge just west of Billinghay to form Billinghay Skirth. At Billinghay village the Skirth has a total catchment area of 95 sq.km. Billinghay Skirth and its embanked fenland tributaries are all Main Rivers.

From Billinghay the Skirth flows east through the main body of the Witham Fens in an embanked channel to enter the River Witham just upstream of Tattershall Bridge. There are no natural inflows to this downstream section of the Skirth and at its outfall its catchment area has only increased to 109 sq.km. There are timber pointing doors across the Skirth's outfall to the Lower Witham.

Car Dyke System

The Car Dyke, like the Fossdyke, is an artificial watercourse of Roman origin and runs along the western edge of the fenland between Lincoln and Peterborough. At one time it was assumed to have been a canal but modern opinion is that it was more probably a catchwater drain associated with fen drainage. Within North Kesteven much of the original course of the Car Dyke is still extant and operates as a catchwater drain.

This is notably so of the section of the Dyke between Washingborough and Billinghay which is a Main River of the Environment Agency, although other isolated sections of the Dyke south of Billinghay also have a comparable purpose and status. Because of its meandering route along the edge of the fens close to the 5mOD contour, the Car Dyke is not regarded as an embanked watercourse.

North of Billinghay the Car Dyke intercepts the various minor spring-fed streams that drain the dip slope of the Lincoln Edge. The fenland between the Car Dyke and the River Witham is intersected by a series of elevated drainage channels known as the Delphs and flows in the Car Dyke are discharged under gravity into the heads of the Delphs. Flows into the heads of the Branston and Metheringham Delphs are now controlled by manually operated penstocks. At Billinghay the Car Dyke discharges to Billinghay Skirth through a small sluice.

The principal streams flowing into the Car Dyke from the limestone ridge to the west are Dunston Beck (catchment area 43 sq.km) and Blankney Beck (30 sq.km).

South Forty Foot Drain

The South Forty Foot Drain is an artificial fen drainage channel which runs northwards and then eastwards in an arc from Guthram Gowt, near Bourne, for a distance of 33km to its outfall into Boston Haven, the tidal outfall channel of the River Witham, at Black Sluice in Boston. Although more than half (364 sq.km) of its 616 sq.km catchment area is pump-drained fenland within the Black Sluice Drainage District it also has a number of tributaries draining the upland area between Bourne and Sleaford.

The South Forty Foot Drain is embanked along its entire length and must therefore be considered a ‘high level carrier’ like the River Witham above Grand Sluice, although along the South Forty Foot the difference between flood levels in the Drain and the level of the adjacent fenland is considerably less. The South Forty Foot and its upland tributaries, which are also embanked, high level watercourses where they cross the fens, are all Main Rivers maintained by the Agency.

Under normal conditions the South Forty Foot Drain discharges under gravity into Boston Haven but, unlike the River Witham, there is a major land drainage pumping station (the Environment Agency’s Black Sluice PS) at the South Forty Foot Drain’s tidal outfall which enables a significant discharge to be maintained from the Drain to Boston Haven at all states of the tide.

The South Forty Foot Drain forms the eastern boundary of North Kesteven for about 6.5km between Donington High Bridge and Swineshead. This means that a substantial area of fenland west of the South Forty Foot within the area administered by the Black Sluice IDB falls within North Kesteven. Four streams which drain the limestone uplands west of the fens cross the fens to the South Forty Foot in embanked watercourses. From the north these are Heckington Eau (Head Dyke), Helpringham Eau, Helpringham South Beck and Swaton Eau, which runs along North Kesteven southern boundary. The latter two watercourses have small natural catchments but Heckington Eau (Head Dyke) (41 sq.km) and, in particular, Helpringham Eau (82 sq.km) both have sizeable upland catchments.

These highland carriers divide the South Forty Foot (Black Sluice) fens into discrete pump-drained flood compartments consisting almost entirely of sparsely populated agricultural land. These pump-drained IDB catchments are described in greater detail later in this Section.

River Slea / Kyme Eau

The River Slea rises near Ancaster, just beyond the western boundary of North Kesteven, and drains much of the Ancaster Gap, a glacial spillway channel cut through the limestone ridge west of Sleaford. At Sleaford the river has a catchment area of 48 sq.km. Groundwater from large limestone springs just upstream of Sleaford is a major component of the flow in the river through the town. The river has a somewhat complex drainage pattern through Sleaford which will be described under the Sleaford Town Study Area in Section 14.

Below Sleaford the river has been diverted into the channel of what was once the Sleaford Canal, leaving its original course, now known as the Old River Slea, as a local low-level drainage channel to the south of the canal route between Sleaford and Anwick. At Cobblers Lock, downstream of Anwick, the two channels recombine. Downstream of this point the river enters the fens and becomes a high-level embanked watercourse known as the Kyme Eau.

Downstream of Sleaford the Slea is joined by its only significant tributary, Ruskington Beck, which drains an area of the dip slope of the limestone ridge north of Sleaford. Where it joins the Slea at Haverholme, the Ruskington Beck catchment (78 sq.km, including Leasingham Beck) is considerably larger than that of the Slea. Apart from a few IDB pump-drained catchments there are no significant inflows to the river along its embanked course through the fens to its confluence with the Lower Witham at Chapel Hill where its total catchment area is 172 sq.km, not substantially greater than where it enters the fens at Anwick.

Fossdyke Canal

The Fossdyke Canal connects the River Trent at Torksey to the Witham at the Brayford Pool in Lincoln. This waterway is, in effect, a backwater of the River Witham and in hydraulic continuity with it as there are no locks or other hydraulic structures along the canal between Lincoln and Torksey. Although the western end of the canal is largely man-made the eastern end appears to be a canalisation of the River Till, a natural tributary of the Witham. This section of the canal is embanked above the adjacent fenland.

A 4km length of the Fossdyke Canal northeast of Skellingthorpe forms the northern boundary of North Kesteven. The south bank of the canal along the boundary is embanked and a breach in this bank could give rise to flooding of the low-lying agricultural land between Skellingthorpe village and the canal. The Skellingthorpe Main Drain, an arterial drainage channel, lies between the canal and the village and would tend to intercept flood flows from the canal and divert them eastwards towards Lincoln. A breach in the canal banks would, however, have a considerable attenuating effect on flood flows through Lincoln and in the Lower Witham.

The River Till, which drains a 118 sq.km catchment extending southwards from near Gainsborough to Saxilby, is the Fossdyke's principal tributary and discharges to the canal at Odder, 2km east of Saxilby. Most of the other inflows to the Fossdyke are from small pump-drained IDB catchments.

River Trent

The River Trent, one of England's largest rivers, drains an area of 8210 sq.km. above its tidal limit at Cromwell Lock. From Cromwell Lock northwards to its outfall into the Humber Estuary, a distance of nearly 70km, the Trent is a tidal river. Although North Kesteven does not extend as far west as the Trent itself, a small area around North Scarle falls within the Trent's tidal floodplain. The village of North Scarle is situated 4km from the Trent and 9km downstream of Cromwell Lock.

Since the long tidal section of the Trent has a relatively narrow channel, compared with other tidal estuaries, much of the tidal section of the Trent is subject to both tidal and fluvial flood risk, although these risks are highly correlated and cannot be considered in isolation. On both sides of the river the Trent is confined between substantial flood defence embankments.

Throughout its tidal section the Trent's traditional flood defence line along its right (east) bank consists of an earth embankment relatively close to the line of the river bank. Between Newark and Gainsborough there is a slight ridge parallel with and about one or two kilometres east of the river, rising to over 20mOD in places. There are, however, gaps in this ridge and in the North Scarle area (as in other locations where there is an extensive area of low-lying land behind the ridge) an additional flood defence embankment has been constructed across these gaps, along the line of the A1133 (Newark to Torksey) road.

The Mill Dam Dyke is a stream which flows through the village of North Scarle on its way to the Trent. At North Scarle it has a catchment area of 25 sq.km. Downstream of North Kesteven's western boundary at Baxter Bridge (A1133) the Mill Dam Dyke is known as Girton Fleet. In previous years the Fleet was tidal for about 750m from the Trent to a tidal outfall sluice at Oak Doors, 600m NW of Girton village, but this sluice has in recent years been superseded by a more modern tidal outfall sluice adjacent to the River Trent.

Between Baxter Bridge and North Scarle village the Mill Dam Dyke is an embanked watercourse. About 50m upstream of Baxter Bridge there is a secondary tidal outfall sluice across the Dyke with a single pair of timber pointing doors. Mill Dam Dyke is now a Main River of the Environment Agency to Clog Bridge, just upstream of North Scarle.

- This page left blank intentionally -

Appendix B - Causes of Flooding

Causes of Flooding

The main sources of flooding have been described in Section 4 However, how those sources perform is also relevant to the causes of flooding as described in the following paragraphs.

Overflowing of Watercourses

When the flow in a river or stream exceeds the capacity of the channel to convey that flow, either because of limited cross-sectional area, limited fall, or a restricted outfall, then the water level in that channel will rise until the point is reached where the banks of the channel are overtopped. Water will then spill over the channel banks and onto the adjoining land. With an upland river the adjoining land is its natural floodplain, which will generally be of limited extent and fairly well defined.

In the case of a substantial river, such as the Witham upstream of Lincoln, the floodplain may be a kilometre or more in width, though it may not be equally distributed on either side of the river channel. However, due to local variations in geomorphology, the width of the floodplain may vary considerably from point to point along the river valley. Floodplains are characterised by flat, riparian land along the valley floor. In pre-industrial England, such land was regarded as liable to flooding and was traditionally reserved for grazing and stock rearing, and human settlements were almost always established on higher land beyond the edge of the floodplain. In the industrial age and more recent times with different priorities, pressures for development have resulted in the widespread colonisation of floodplains, often with steps taken to mitigate the associated risks of flooding, such as the construction of embankments (floodbanks) on either side of the river channel to confine flood waters within that channel.

When overtopping of an embanked watercourse, such as the Witham downstream of Lincoln, occurs, it will take place over a substantial length of bank and hence the depth of water flowing over the flood bank or floodwall will probably be small, a few centimetres at most. The bank will act like a weir and the rate of flow per unit length of bank will be relatively modest and this, provided that the duration of overtopping is finite, will limit the volume of water cascading over the defences to cause flooding within the defended area. If overtopping does occur and the area liable to flooding is of considerable extent, any flooding which results will often be disruptive rather than disastrous. The situation becomes far more critical if overtopping of an earth embankment erodes its crest, leading to a breach in the embankment. This situation is considered below.

Breaching of Embankments

An earth embankment may be breached as a direct result of overtopping. Water overflowing a flood bank, especially when concentrated over a short length of bank, results in a rapid flow of water down the rear slope of the bank. This can cause erosion, which starts at the rear of the bank and works its way forward towards the river channel or source of the flooding. As the crest of the bank is washed away the flow through the small initial gap increases and a small breach is created. This becomes steadily bigger as water flows through it, eroding the sides and base of the breach, and a rapid and progressive failure of the embankment follows. In an extreme event, complete collapse of the bank may take only minutes. The contents of the embanked channel then pour through the breach and across the now exposed hinterland.

A tarmac road or dwarf floodwall along the crest of a flood bank may inhibit the rate of initial erosion and postpone or even prevent the creation of a breach, depending upon the duration of overtopping. Experience, fortunately limited, shows that when a fluvial flood bank breaches, even if not by overtopping, it does so near the peak of the flood when the flow in the river and hence flood levels are at or near their maxima. Experience also suggests that breaches in river embankments usually extend from 20 to 30 metres in length and rarely grow to more than forty metres. Unlike tidal defence floodbanks, once a breach in a fluvial flood bank has occurred there will be a reduction in flood levels in the river as water flows through the breach. This reduces the stress on neighbouring floodbanks along the same reach of river, thus considerably reducing the risk of further breaches in the same area.

The design of a flood bank (or floodwall) incorporates a certain level of freeboard to allow for uncertainties, bank settlement, wave action, etc. but the height of any flood bank is determined primarily by the peak height of the design flood. Because of freeboard, the return period of the flood which gives rise to overtopping must in reality be somewhat greater than that of the design flood. The return period of flooding from a breach caused by overtopping will be essentially the same as for the far less severe flooding resulting from that overtopping alone, but it must be borne in mind that breaches in earth embankments can occur from causes other than overtopping and may thus have return periods significantly less than the that for which the flood bank was designed. This is known as “residual risk” flooding.

Apart from overtopping, breaches in floodbanks can occur where weak spots in the bank have been created over a long period by gradual leakage through the bank at old, forgotten structures buried in the bank such as culverts or sluices (‘slackers’), or where the activities of burrowing animals such as rabbits or coypu have impaired the integrity of a flood bank. These inherent weaknesses may not be readily apparent under normal conditions but when significantly high water levels occur in the river, a failure may occur, quickly giving rise to a breach. This may well happen in a flood of considerably lesser magnitude and return period than the design flood.

Furthermore, since the inherent weakness tends to increase slowly with age, the fact that a bank did not fail in an earlier flood does not guarantee that it will not fail in a comparable (or even a lesser) flood at some time in the future. If, however, a flood bank is of recent construction it may be assumed that it has been properly engineered and, provided that there is an adequate inspection and maintenance regime, the risk of breaching as a result of the factors outlined above is negligible.

Mechanical, Structural or Operational Failure

Although less common than overtopping or breaching of defences, flooding can also be caused by the mechanical or structural failure of engineering installations such as land drainage pumps (or their power supplies), sluice gates (or the mechanism for raising or lowering them), lock gates, outfall flap valves etc. Such failures are, by their nature, more random and thus unpredictable than the failures described in the previous sub-Sections, and may occur as a result of any number of reasons. These include poor design, faulty manufacture, inadequate maintenance, improper operation, unforeseen accident, vandalism or sabotage.

Structural failure, in this context, is also taken to include the failure of ‘hard’ defences in urban areas such as concrete floodwalls. ‘Hard’ defences are most unlikely to fail by the overtopping / erosion / breaching sequence experienced by earth embankments. Their failure tends to be associated with the slow deterioration of structural components, such as rusting of steel sheet piling and concrete reinforcement, or the failure of ground anchors. Such deterioration is often difficult to detect and failure, when it occurs, may well be sudden and unforeseen. Structural failure of ‘hard’ defences is most likely to happen at times of maximum stress, when water levels are at their highest during a flood. Failure of hydraulic structures and ‘hard’ defences can, under certain circumstances, be precipitated by the scouring of material from beneath their foundations by local high velocity flows or turbulence, especially under flood conditions.

Flooding can also be caused or exacerbated by the untimely or inappropriate manual operation of sluices, or by the failure of the person or organisation responsible to open or close a sluice at a critical time. Responsibility for the operation of sluices rests with various public bodies as well as riparian landowners. Operational failures of this nature generally occur during a flood event and their results are to exacerbate rather than to cause flooding, and their impact is normally limited in extent.

Flooding, especially that caused by overflowing of watercourses, can be exacerbated by other operational failures. These failures can also include neglected or inadequate maintenance of watercourses resulting in a reduction of their hydraulic capacity. Flooding can also be caused or exacerbated by bridge or culvert blockages, although these are not necessarily due to maintenance failures and may be caused by debris, natural or man-made, swept along by flood flows.

The risks associated with this category of failures are almost impossible to quantify, especially as experience has shown that there is a joint probability relationship between this class of failure and flooding resulting directly from extreme meteorological events. It can of course be argued that if a risk of this type was quantifiable and found to be finite then action should already have been taken to alleviate the risk. Even an assessment of relative risk for failures of this type must depend on a current and detailed knowledge of the age and condition of plant, its state of maintenance, operating regime etc at a significant number of disparate installations. Mechanical, structural and operational failures are typical ‘residual’ flood risks.

Floodlocking and Tidelocking

During a flood the water level in a river will rise above the ground level in areas defended by floodbanks or floodwalls. Surface water sewer outfalls which discharge through the flood defence line will, of course, be fitted with a non-return flap valve to prevent flood water entering the defended area from the river through the sewer.

However, if there is heavy rainfall over the defended area (or the surrounding area) while the river is in flood, all surface water runoff from the defended area (or areas draining through the defended area) will be impounded behind the flood defences until such time as the river level falls and gravity discharge can recommence. This phenomenon is known as ‘floodlock’ and can give rise to secondary flooding within the defended area, even though the defences may not have been overtopped or breached.

If the main flood event is caused by heavy frontal rainfall over the whole river catchment and the defended area is an urban area, the rapid urban runoff from the defended area will probably have entered the river well before the flood peak in the river reaches the defended area, in which case secondary flooding due to ‘floodlock’ will not occur. Secondary flooding of this nature is therefore only likely to occur if there is a second, subsequent rainstorm over the urban area, or if the main frontal rainfall which caused the river to flood is prolonged and moves slowly down the catchment towards the urban area. In either event, secondary flooding in urban areas due to ‘floodlock’ is an unusual occurrence.

The effects of ‘floodlock’ can be overcome by the installation of land drainage pumps behind the defence line so that the flows in the floodlocked sewers or watercourses can be pumped into the river and thus prevented from accumulating behind the defences and causing secondary flooding there. Without pumping, ponding of surface runoff will start to occur at the lowest points in the defended area. If the ponded runoff originates just from within the defended area the resultant flooding will be relatively shallow and of limited extent, probably only of nuisance value. If, however, the runoff originates from a source outside the defended area - a ‘floodlocked’ tributary stream with a substantial catchment area - the volume of runoff may be large, in which case the depth and extent of the secondary flooding could, in the extreme, be comparable to that which would have occurred in the defended area had the defences not been present.

Large areas of North Kesteven, particularly in the Witham Fens and South Forty Foot Fens, are pump-drained by Internal Drainage Boards into the higher level Main Rivers which are embanked above the fenland through which they flow. Floodlocking can therefore be a potentially significant component of flood risk in these areas if drainage pumps fail or their capacity is exceeded by the flow reaching the pumps.

'Tidelock' is essentially similar to 'floodlock' except that the obstruction of the local gravity drainage outfall is due to a high tide rather than a fluvial flood. Whereas floodlocking is, by definition, a relatively rare occurrence, tidelocking is often being a regular and frequent occurrence. 'Tidelock' flooding can occur during a normal high tide if the peak of the tide coincides with a rainstorm over the tidelocked area, but because the period of tidelock is confined to the peak of the tide its duration is generally limited and any flooding is both minor and localised. Longer periods of tidelock may occur during a storm surge and in that case the resultant flooding could have a greater impact, but would depend upon the coincidence of the peak of the storm surge with heavy rainfall.

Although there are no tidal flood defences within North Kesteven (i.e. coastal defences or floodbanks along tidal estuaries) tidelocking can have a significant impact on flood risk in the Witham Fens and, to a lesser extent, in the South Forty Foot Fens The River Witham discharges by gravity through Grand Sluice, its tidal outfall in Boston. When this sluice is tidelocked, discharge cannot take place and water levels in the river rise steadily until tidelock ceases and discharge from the river to the river's tidal estuary (Boston Haven) is again possible. The South Forty Foot Drain also has a gravity discharge to Boston Haven at its tidal outfall at Black Sluice but, unlike the Witham, discharge from the Drain to the Haven can be maintained at times of tidelock by pumping at Black Sluice Pumping Station.

<u>Localised Flooding</u>

Almost all localised flooding of a serious nature occurs as a result of a severe convective storm, localised in extent and duration and generally during the summer. This flooding can, however, be exacerbated by two factors, blockages in the local surface water drainage system or by 'floodlocking'. Each of these factors is considered separately below. In some instances, in what would otherwise have been a relatively moderate rainstorm, these factors can themselves be the cause of flooding.

Intense storm rainfall, particularly in urban areas, can create runoff conditions which temporarily overwhelm the capacity of the local sewerage and drainage systems to cope with the sudden deluge. Localised 'flash' flooding then occurs.

Localised flooding can also occur in urban areas where a stream or watercourse has been extensively culverted. In its natural state, if the channel capacity of a stream is exceeded the channel will overflow along a considerable length and the resultant flooding is distributed over a wide area. If, however, the stream runs through a long culvert and the hydraulic capacity of that culvert is exceeded under flood conditions the culvert becomes surcharged at its upstream end. Water levels will then rise rapidly and localised flooding upstream of the culvert, often quite serious, can occur. The flood water, in attempting to follow the natural line of the culverted watercourse, may also flow through the built-up area above the line of the culvert. This applies equally to many larger surface water sewerage systems in urban areas which are, in effect, culverted watercourses.

Local flooding is often exacerbated by deficiencies in the local surface water drainage system, but these can usually be remedied by relatively minor works once they have been exposed by a flooding event. Local flooding can also be caused by temporary blockages or obstructions in a drainage system, especially one that has been extensively culverted. Such flooding can therefore be virtually random in its occurrence, although the prevalence of blockages at a particular location would suggest a systematic problem, justifying action to modify the drainage system at that location in order to resolve it.

Because of much of the District's relatively flat topography, many of the local drainage systems are either pumped into the receiving watercourse, or discharge under gravity into a watercourse which is itself pump-drained. In either case 'floodlocking' as described above will not occur unless the event is so severe that the installed pump capacity is exceeded by the rate of runoff reaching the pumps.

- This page left blank intentionally –

Appendix C - Internal Drainage Boards

Internal Drainage Boards

Black Sluice Drainage District

The Black Sluice IDB operates a total of 37 land drainage pumping stations throughout its area of which eight serve catchments wholly or partly within North Kesteven. These pumping stations are listed in Table C1 below.

Pumping Station	Pumps to	Area drained (km^2)	Maximum capacity (cu.m/sec)	Number of pumps	Design max. w.l. (mOD)
Swaton	Sth Forty Foot Drain	8.51	1.13	1 (+g)	+0.15
Helpringham	Sth Forty Foot Drain	8.14	1.33	1 (+g)	0.00
Great Hale	Sth Forty Foot Drain	23.63	3.48	3 (+g)	-0.30
Heckington	Head Dyke	15.77	2.66	2	-0.60
Ewerby	Tributary of Head Dyke	11.41	2.24	3 (+g)	-0.30
South Kyme	Head Dyke	11.01	1.30	2 (+g)	-0.60
Trinity College	Head Dyke	6.09	1.13	2 (+g)	-0.60
Damford Grounds	Kyme Eau	8.93	1.19	2	0.00

Notes: 1) (+g) indicates that a gravity discharge is possible at that PS.
2) Only the western edge of the Trinity College PS catchment is in N.Kesteven.

Table C1 - Arterial Drainage Pumping Stations - Black Sluice District

The Board's watercourses have been designed to provide a minimum freeboard of 0.6m in that watercourse in a 1 in 10 year flood event. This minimum freeboard is the difference between the flood level and the level of the lowest land in the catchment, so far as is practical without creating excessive freeboards elsewhere. The Black Sluice IDB expect their pumping stations and the watercourses that the Board maintains to provide a standard of protection against flooding of at least 1 in 50 years, although intense localised storms may still cause local flooding. However, the Board have an agreement with the Environment Agency that pumping into the Agency's high-level South Forty Foot Drain system will cease when water levels in the Drain and its high-level tributaries reach critical levels.

It should be noted that a number of the Main Rivers into which the Board's pumping stations discharge, particularly the Head Dyke / Skirth Drain, have a standard of protection of less than 1 in 10 years although the impact of flooding from those Main Rivers would largely be confined to agricultural land.

Although the Black Sluice IDB has undertaken the hydraulic modelling of a number of their larger pump-drained catchments in the Boston area, none of their pump-drained catchments in North Kesteven has yet been modelled.

Witham First Drainage District

The area administered by the Witham First District IDB is generally coincident with the extensive area of fenland that stretches along the west bank of the Lower Witham from Washingborough on the east side of Lincoln to the River Slea (Kyme Eau) and the outskirts of Sleaford. The whole of the Drainage District lies within North Kesteven.

The Witham First District IDB operate thirteen land drainage pumping stations within their area. These are summarised in Table C2 below.

Pumping Station	Pumps to	Area drained (km^2)	Maximum capacity (cu.m/sec)	Number of pumps
Sandhill Beck	South Delph	1.70	0.85	1
Heighington Fen	South Delph	7.96	1.11	2
Branston Fen	South Delph	8.44	1.18	2
Nocton	Lower Witham	16.68	2.34	2
Metheringham	Lower Witham	14.48	2.10	2
Blankney	Lower Witham	21.37	2.65	2
Timberland	Lower Witham	20.65	2.93	3
Billinghay	B'hay Skirth	6.64	0.93	1
Digby	B'hay Skirth Trib	7.29	1.01	2
Farroway	B'hay Skirth Trib	16.20 (h) 12.10 (l)	2.62	3
Ringmoor	B'hay Skirth Trib	0.15	0.06	1
Chapel Hill	Kyme Eau	10.00	2.50	2
Nth Kyme Booster	Internal	7.87	1.01	2

Notes: 1) Farroway PS drains a high-level catchment and a low-level (fen) catchment.
2) North Kyme BPS is within the Chapel Hill PS catchment.

Table C2 - Arterial Drainage Pumping Stations - Witham First District

A number of the pump-drained catchments listed in Table 4.2 are interconnected. Washingborough Fen (Sandhill Beck PS) and Heighington Fen are linked by an inverted siphon under Sandhill Beck. Branston Fen and Nocton Fen (Nocton PS) are not connected but are only separated by a small earth bund, the Branston Causeway (B1190). The Timberland Fen and Billinghay Fen catchments are linked at several locations by inverted siphons and open channels.

The Witham First District IDB have provided details of operating control levels in at their pumping stations. These are summarised in Table C3 overleaf.

Catchment	Winter Control Levels (Start of pumping - mOD)			Max. Summer Control Level (mOD)
	1st Pump	2nd Pump	3rd Pump	
Sandhill Beck	+0.30	-	-	+1.1
Heighington Fen	-1.00	-0.50	-	+0.5
Branston Fen	-2.00	-1.70	-	0.0
Nocton	-1.40	-1.00	-	0.0
Metheringham	-1.30	-1.00	-	-0.1
Blankney	-1.40	-1.20	-	-0.6
Timberland	-1.40	-1.20	-0.90	-0.4
Billinghay	-1.00	-	-	-0.4
Digby	-1.30	-0.60	-	-0.2
Farroway (High Level)	+1.30	-	-	+2.0
Farroway (Low Level)	-0.80	-0.60	-	-0.1
Chapel Hill	-0.60	-0.50	-	0.0
Nth Kyme Booster	-0.90	-0.60	-	0.0

Notes:
1) The control level is the highest level reached before pumping begins.
2) Farroway PS drains a low-level (fen) catchment and a higher-level catchment.
3) North Kyme Booster PS is within the Chapel Hill PS catchment.
4) The very small Ringmoor PS has been omitted.

Table C3 - Arterial Drainage System Control Levels - Witham First District

The Witham First District IDB estimates that the current standard of flood protection in the pumped catchments in their District is between 1 in 50 and 1 in 75 years. The Board also states that the significant capital works that they have undertaken in the past forty years to ensure that the internal standard of drainage in the District is at its highest level possible, given the constraints to which the Board is subject, and that any problems within the District result wholly from matters outside the Board's control.

Unlike the Black Sluice IDB the Witham First District IDB does not have any agreement with the Environment Agency, either formal or informal, regarding cessation of pumping to the Agency's high-level river system, but the Board anticipates that discretion in this respect would be appropriately applied in any emergency.

Although it lies northeast of the River Witham, Branston Island falls within the Witham First Drainage District. Until about five years ago Branston Island was drained by an Environment Agency pumping station but this station has been demolished and replaced with a sump for a portable pump which is the responsibility of the occupier of the agricultural land within Branston Island.

Upper Witham Drainage District

The area administered by the Upper Witham IDB lies between the Lincoln Edge and the Trent Valley and stretches from Gainsborough in the north to beyond Grantham in the south. The District can be considered in two parts, divided by the Fossdyke Canal. The part north of the Fossdyke Canal - the River Till catchment - falls outside North Kesteven and need not be considered further in this study. The part south of the Fossdyke lies within both North and South Kesteven Districts but with small areas of the Drainage District in both Nottinghamshire and the City of Lincoln.

The Upper Witham IDB operates a total of fifteen land drainage pumping stations throughout its area of which seven serve catchments wholly or partly within North Kesteven. These pumping stations are listed in Table C4 below.

Pumping Station	Pumps to	Area drained (km^2)	Maximum capacity (cu.m/sec)	Number of pumps
Oxpasture	F'dyke Canal	18.40	4.20	3
Fen Lane	Note 1	2.88	0.50	1
Decoy	Note 1	2.57	0.50	1
Pyewipe	F'dyke Canal	17.28	3.40	3
Hykeham	River Witham	5.40	0.79	1
Aubourn	River Brant	6.36	1.00	2
Sand Syke	River Brant	7.81	1.00	2

Notes:
1) Fen Lane and Decoy PSs are booster stations pumping to Skellingthorpe Main Drain within the Pyewipe PS Catchment.
3) Only the southern half of the Oxpasture catchment is in North Kesteven.
4) Part of the Pyewipe catchment is outside North Kesteven.
5) The three original diesel-engine pumps at Pyewipe are maintained as standby (2.95 cumec additional capacity not included above).

Table C4 - Arterial Drainage Pumping Stations - Upper Witham District

The Aubourn and Sand Syke pumping stations form part of the Environment Agency's Lincoln Flood Alleviation Scheme, Witham and Brant Washland sites respectively. The Agency maintains its own pumps at each site for pumping out the washlands after flooding, also utilising the IDB's pumps for that purpose.

Although Saxilby pumping station lies almost on the North Kesteven boundary north of Skellingthorpe its pumped catchment lies wholly outside North Kesteven. There is, however, a link between the Saxilby and Pyewipe pumped catchments which permits flood water to flow from the former to the latter, but not vice versa. Under extreme conditions it would therefore be possible for flood water from the Broadholme area, south of the Fossdyke Canal in West Lindsey, to enter the head of the Skellingthorpe Main Drain.

There is a two-way link between Pyewipe and the Boultham / Coulson Road pumped catchment which drains the Lincoln urban area west of the Witham. The Pyewipe catchment is also linked to the Burton pumped catchment (north of the Fossdyke) by a large diameter culvert under the Fossdyke.

Operating control levels for the Upper Witham IDB pumping stations are given in Table C5 overleaf.

Catchment	Winter Control Levels (Start of pumping - mOD)			Max. Summer Control Level (mOD)
	1st Pump	2nd Pump	3rd Pump	
Oxpasture	+4.03	+4.18	+4.43	+4.4
Fen Lane	+1.55	-	-	+1.9
Decoy	+1.90	-	-	+1.9
Pyewipe	+2.70	+2.90	+3.05	+2.9
Hykeham	+3.14	-	-	+3.1
Aubourn	+3.70	+4.10	-	+3.7
Sand Syke	+4.90	+5.10	-	+4.9

Notes:
1) The control level is the highest level reached before pumping begins.
2) Fen Lane PS and Decoy PS drain low-level (fen) catchments on either side of Skellingthorpe Main Drain but are linked by a siphon beneath the Drain.

Table C5 - Arterial Drainage System Control Levels - Upper Witham District

As far as we are aware, the Upper Witham IDB has not yet undertaken hydraulic modelling of any of their pump-drained catchments within North Kesteven.

The Upper Witham IDB do not have estimates of flood levels at key locations in their arterial drains for the 100-year return period event, but a recent flood risk assessment for the Lincoln Western Growth Corridor gave an estimated 100-year flood level of 4.25mOD in the Skellingthorpe Main Drain (Pyewipe catchment).

Newark Area Drainage District

The Newark Area Drainage District runs down the Trent Valley along both banks of the River Trent from upstream of Newark to Gainsborough. A small part of North Kesteven on the western edge of the District falls within the Drainage District, but the only significant area of North Kesteven which falls within the area administered by the Newark Area IDB is the Mill Dam Dyke catchment. This includes the village of North Scarle, the HM Prison at Morton and extends to the edge of the recent Witham St Hugh's development (RAF Swinderby). Outside this catchment a small area of agricultural land west of Swinderby railway station and a strip of land up the western edge of Stapleford Woods are also in the Newark Drainage District.

The Newark Area IDB operates eight land drainage pumping stations which drain low-lying land along the Trent, but none of them is in North Kesteven. Although the Mill Dam Dyke is an arterial watercourse it has a gravity outfall to the River Trent at Girton and its catchment is not pump-drained.

The downstream end of the Mill Dam Dyke, from the River Trent to the North Kesteven boundary at Baxter Bridge on the Gainsborough Road (A1133) northeast of Girton village, is what was once a tidal backwater of the Trent known as Girton Fleet. Even though an outfall sluice now prevents ingress of tidal water from the Trent, Girton Fleet is still subject to 'tidelock' conditions and water levels in the Fleet, and to a lesser extent the Mill Dam Dyke upstream of Baxter Bridge, are controlled by the Fleet's tidal outfall sluice and, under extreme conditions, the secondary sluice at Baxter Bridge.

When the Trent is in flood the Mill Dam Dyke can become ‘floodlocked’ and cannot discharge to the Trent. Both banks of the Dyke are embanked along Girton Lane as far upstream as North Scarle and in 2004 the IDB reinforced the north (right) flood bank downstream of Hunts Bridge with steel sheet piling to protect the low-lying land north of the watercourse. Although now defended from flooding from the Mill Dam Dyke, the IDB considers that North Scarle village is still at risk of flooding from the Trent in an extreme fluvial event.

If flows in the Mill Dam Dyke under tidelock or floodlock conditions are large enough for its channel to be overtopped, this will occur along the south (left) bank of the channel between Baxter Bridge and North Scarle, causing inundation of low-lying land between the village and Baxter Bridge.

Since its adoption as Main River, the Environment Agency has undertaken the hydraulic modelling of the Mill Dam Dyke from Baxter Bridge to the centre of North Scarle village. The model has given estates of the 100-year return period flood levels ranging from 6.73mOD at the Baxter Bridge sluice to 7.74mOD in the centre of North Scarle, with intermediate levels of 7.01mOD at Sandilands and 7.46mOD at Hunts Bridge. The Environment Agency states that the flood bank through the village from Church Lane Bridge to Chapel Lane (crest level approximately 6mOD) gives a 1 in 100-year standard of flood protection.

The Mill Dam Dyke carries the drainage from a considerable length of the main A46 (Lincoln – Newark) road in the Swinderby area but comprehensive runoff attenuation measures were put in place when the road was recently reconstructed as a dual carriageway by the Highways Agency.

Appendix D - Breach Analysis Methodology

Breach Analysis Methodology

<u>Objective</u>

The objective of the methodology is to consider the detailed nature of flood hazard within a FZ. This is achieved by simulating the effect of breaches in the raised fluvial defences and the subsequent propagation pattern of flood water flowing through that breach into a flood compartment using one-dimensional (1D) and two-dimensional (2D) hydraulic modelling techniques.

<u>Modelling Software</u>

The 1D hydraulic modelling software ISISv3.0 coupled with the 2D hydraulic modelling software package ‘Tuflow’ (Build TUFLOW.2008-08-AB-iSP) was used to model the effect of breaches in the raised fluvial defences along the Lower River Witham, South Delph, Billinghay Skirth, Kyme Eau and the South Forty Foot Drain.

<u>Breach Locations</u>

In order to model the effect of flood water issuing from a breach in the flood defences along embanked fluvial watercourses, a total of 8 breach locations were selected. These breach locations were selected, after discussion and agreement with the Environment Agency, to give a pattern of flooding representative of a breach in a typical flood compartment in which that breach occurred.

<u>Model Input and Sources of Data – Hydrology of Flood Risk Sources – ISIS Models</u>

The level of the water retained by the flood defence when overtopping and/or a breach occurs has a major influence on the rate and volume of flow through the breach (or over the defence if only overtopping occurs) and hence on the extent of the flood envelope and the depths and velocities of water in the hazard zone. Each 1D ISIS model of the channel was coupled was a 2D Tuflow model of the floodplain.

<u>River Witham ISIS Model</u>

The Environment Agency provided a 1D ISIS hydraulic model of the Lower Witham and modelling results for the 1 in 10, 1 in 25 and 1 in 100 year events. The Lower Witham model extends from Stamp End Sluice in Lincoln to its tidal outfall to the Haven at Boston and incorporates all of the River Witham’s major tributaries including the South Delph, Barlings Eau, Kyme Eau and River Bain. This model was developed during 2000-2002.

For each of the breach locations the Lower Witham ISIS model was adjusted to only include a certain stretch of the River(s) that would be impacted by a breach in that particular location.

River Witham Breach Locations

Table D1 below shows the extent of the ISIS models used in the River Witham Breach scenarios.

Breach Location	Upstream Extent	Lower Witham Model Node	Downstream Extent	Lower Witham Model Node
Nocton	Bardney Lock	Owit1d	Langrick Bridge	With8bd
Dogdyke	Kirkstead Bridge	With34	Langrick Bridge	With8bd

Table D1 - Extents of ISIS Models used for River Witham Breaches

For both of the above ISIS models all of the left bank floodplain was included as per the existing Lower Witham model as well as all of the right bank floodplain except within the breach cell – (between Branston Delph and Nocton Delph for Nocton breach and between Billinghay Skirth and Kyme Eau for Dogdyke breach).

The upstream boundary of the models was a QT boundary and the downstream a HT boundary. All inflows and outflows from the ISIS model were extracted from the existing Lower Witham ISIS model in order for modelled results to be replicated in the trimmed models. The ISIS model was coupled with the 2D floodplain only into each breach flood cell – see above for details.

South Delph ISIS Model

The South Delph is modelled within the Lower Witham model flows from Stamp End Sluice in Lincoln to its downstream extent at Bardney Lock. The South Delph flows parallel to the River Witham for the whole of this extent.

The Lower Witham ISIS model was trimmed to represent the River Witham in South Delph in the vicinity of the breach at Washingborough. The trimmed model extends from Stamp End Sluice in Lincoln (model node labels sd498 & uwth500) to Branston Island (model node label uwith395u). All of the left bank floodplain was included as per the Lower Witham model.

The upstream boundary of the model was a QT boundary and the downstream a HT boundary. All inflows and outflows from the ISIS model were extracted from the existing Lower Witham ISIS model in order for modelled results to be replicated in the trimmed model. The ISIS model was coupled with the 2D floodplain between Stamp End Sluice to just downstream of Middle Fen Lane.

Billinghay Skirth ISIS Model

The Billinghay Skirth flows from SW to NE and is modelled in the Lower Witham Model from the Car Dyke to its confluence with the River Witham just upstream of Tattershall Bridge. The Billinghay Skirth is connected to the River Witham via pointing doors. During flood events the pointing doors close and no water is able to flow into the Billinghay Skirth from the River Witham. For this reason the Billinghay Skirth was lifted from the Lower Witham ISIS model and developed into its own stand alone model.

The upstream extent of the model was its junction with the Car Dyke and was modelled as a QT boundary. The downstream extent of the model was the pointing doors just upstream of its confluence with the River Witham and was modelled as a Q~H boundary – see Figure D2 below.

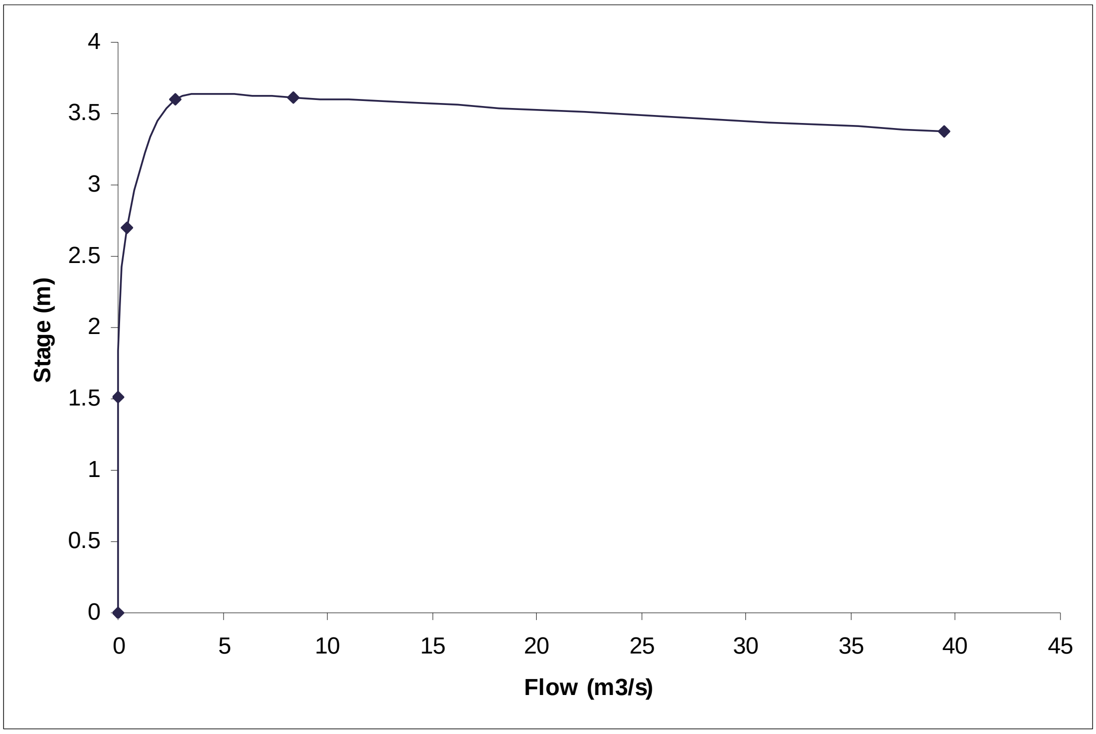

Figure D1 - Q~H Boundary to model the Pointing Doors on the Billinghay Skirth

The 1D river channel is coupled to the 2D floodplain 1.5km upstream of the upstream limit of the ISIS model to the ISIS model downstream extent. Extending the link upstream of the ISIS model creates a limitation of the model as overtopping occurs in this area causing a certain volume of water to spill into the floodplain here rather than go through the breach.

<u>Kyme Eau ISIS Model</u>

The Kyme Eau flows from west to east through South Kyme before flowing northerly to join the River Witham at Chapel Hill. The Kyme Eau is connected to the River Witham via pointing doors. During flood events the pointing doors close and no water is able to flow into the Kyme Eau from the River Witham. For this reason the Kyme Eau was lifted from the Lower Witham ISIS model and developed into its own stand alone model.

The upstream extent of the model was Cobblers Lock and was modelled as a FEH boundary. The downstream extent of the model was the pointing doors just upstream of its confluence with the River Witham and was modelled as a Q~H boundary – see Figure D3 below.

The ISIS model was coupled to the floodplain from South Kyme to its downstream extent.

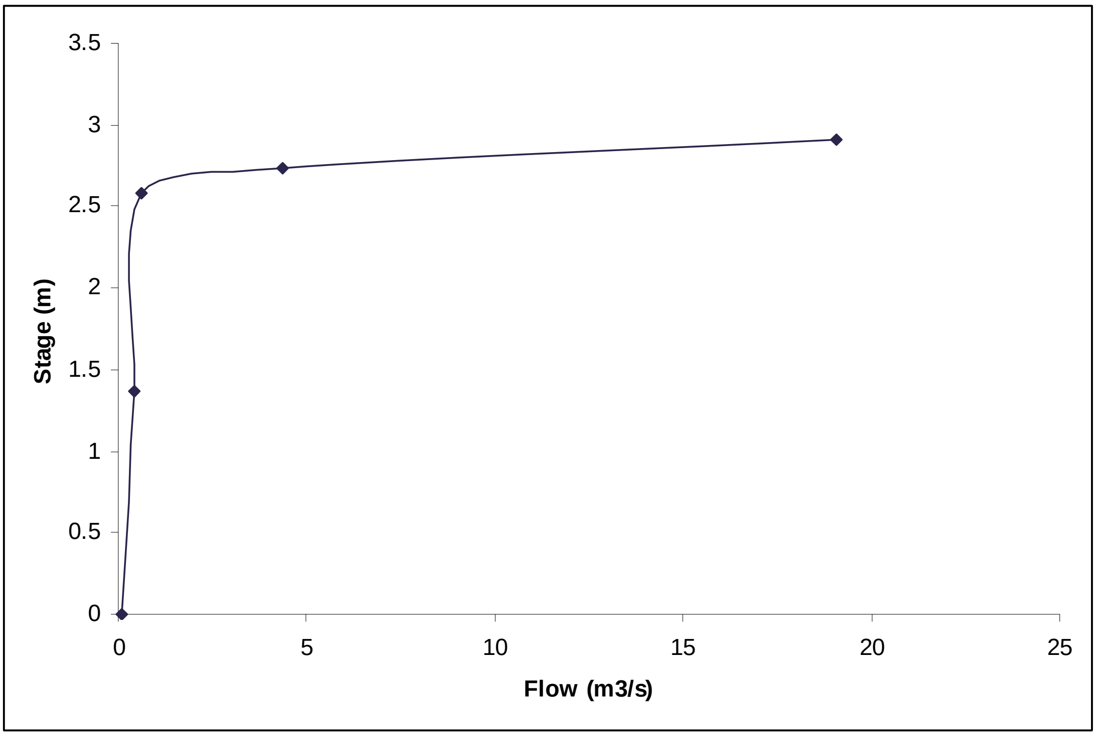

Figure D2 - Q~H Boundary to model the Pointing Doors on the Kyme Eau

South Forty Foot Drain

The Environment Agency provided a 1D hydraulic model of the South Forty Foot Drain and modelling results for the 1 in 10 year, 1 in 25 year and 1 in 100 year events. The South Forty Foot model extends from just upstream of Casswell's Bridge to its downstream extent at Black Sluice Pumping Station in Boston and includes many of its major tributaries including Helpringham Eau.

The original model was adapted to version 4.4 in the pump rules to enable the model to begin its simulation. The spills to storage compartment (SF116000SL, SF114000SL, SF113000SL, and SF112500SL) and storage unit GH were trimmed to enable coupling with Tuflow 2D floodplain.

The ISIS model was coupled to the floodplain between Helpringham Fen and the Sleaford to Boston railway line.

Model Input Data and Sources of Data – Topography

The ground elevation model of the fens was based on filtered LiDAR (Light Detection And Ranging) digital terrain model data supplied by the Environment Agency. Filtered LiDAR is essentially a bare earth model and excludes the presence of buildings and vegetation.

Any key features on the floodplain within the flood cell were manually input into the ground model so that these features and their impact on flood flows within the cell could be represented correctly.

A 10 metre grid size was used for all of the ground models (i.e. ground levels at 10m intervals).

Model Input Data and Sources of Data – Defences

The spatial locations of the defences were derived from the Environment Agency's National Flood & Coastal Defence Database (NFCDD) dataset. The defence type has been taken from the NFCDD and, where possible, verified by observations made during site visits.

All defence crest levels have been taken from the corresponding ISIS models. This was to aid in the coupling with the floodplain so that when water spilled overbank from the ISIS cross section, the water could flow into the 2D floodplain. Any secondary defences within the District have been incorporated as topographical features in the surface model by increasing the ground level to the defence crest level given in the NFCDD dataset.

Ground levels immediately to the rear of the breach in the defences have been obtained from the LiDAR data.

Model Input and Sources of Data – Surface Roughness (Manning's 'n' Coefficients)

The rate at which flood water will flow overland across a floodplain from a breach in a defence line will be strongly influenced by the roughness of the ground surface over which it flows. This will in turn depend on the state of cultivation of farmland and the density and height of any vegetation in the path of the floodwater. (Large, solid obstructions such as buildings are accounted for in the LiDAR ground model data.) The numerical values of Manning's 'n' coefficients provide a standard estimate of surface roughness in hydraulic calculations. All of the breach models utilised the Manning's 'n' roughness coefficients shown in Table D2 below.

Manning's 'n' Value	Description
0.02	Roads, concrete, paved surfaces etc
0.035	Maintained river channels
0.04	Mown fields (playing fields etc)
0.05	Grazed fields or meadows (Default value)
0.055	Scrubland
0.08	Residential urban (accounts for gardens, fences etc)
0.10	Trees and woodland
0.15	Dense urban

Table D2 - Mannings 'n' Coefficients used in Breach Modelling

Model Input and Sources of Data – Breach Parameters

Breaches were modelled on the assumption that the breach occurred in the defence at the peak flood level during the event and took 0.5 hours to develop fully. The level of the defence was reduced to the landward ground level behind that defence. This assumption produces a conservative flood envelope for the extent of the flooding resulting from the breach.

The breach parameters for all the breach locations were based on guidance provided by the Environment Agency. The maximum depth of the breach was assumed to be the ground level at the landward toe of the defence. Ultimate breach widths in earth embankments were 40m and the time taken to close the breach was 40hrs.

Other Modelling Assumptions

It was also assumed that no flood water would enter the high level tributaries from the Lower Witham as a result of the breach in a tributary's defences because of the presence of 'pointing doors' at the confluence of the tributary and the Witham which would prevent backflow from the Witham into the tributary. Since the volume of flood water present in the Lower Witham can be an order of magnitude greater than that present in the tributary the impact of a breach in a Lower Witham floodbank would be significantly greater than that from a tributary breach therefore, with the exception of the Billinghay Skirth and Kyme Eau, it was only necessary to model the effect of breaches in the Witham flood banks and not those along its tributaries.

Modelling Scenarios

For each of the 8 breach locations only the 1 in 100 year return period event has been modelled and outputs produced. This is because there is a minimal difference between flood levels in the Lower Witham system for return periods above 50 years.

Modelling Outputs

Appropriate scale maps showing:

- Flood Depth at all grid points within the flood cell
- Flood Velocity at all grid points within the flood cell
- Hazard (Rapid Inundation) Zone envelopes, using flood hazard rating formula.

The flood hazard rating formula gives Flood Hazard = ((v+0.5)*D)+DF

where:- V = velocity (m/s)

D = depth (m)

DF = debris factor.

The debris factor has been taken as 0.5 for depths up to 0.25m and a debris factor of 1 has been taken for depths above 0.25m (Technical Report FD2320). The hazard zone maps show the danger for people based on Table 13.1 in Technical Report FD2320.