West Lindsey District Council

STRATEGIC FLOOD RISK ASSESSMENT

SFRA Final Report – July 2009

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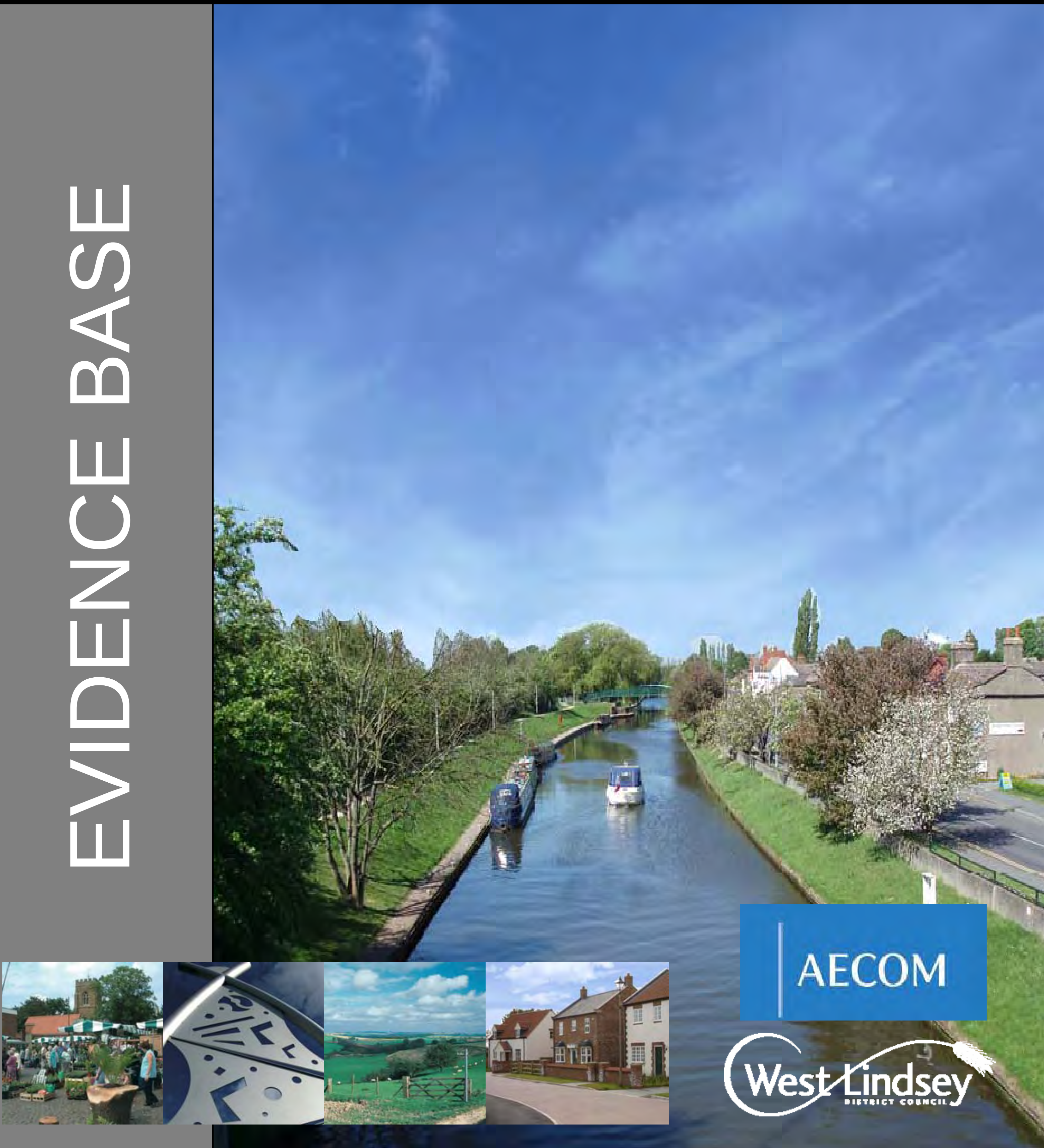

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West Lindsey
DISTRICT COUNCIL

Prepared by: .... Clare Marsh
Graduate Engineer

Checked by: .... Philip McLoughlin
Regional Director

Approved by: .... Roy Lobley
Associate Director

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

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As of 4th May 2009, Faber Maunsell Limited has changed its name to AECOM Limited and has rebranded as AECOM, as part of our parent company's strategy to integrate across business lines and regions globally.

AECOM is a global provider of professional technical and management support services with over 43,000 people in more than 100 countries and is a leader in the delivery of Building Engineering, Transportation, Water, Environment, Programme Management, Energy and Planning & Design services. As a result of this global integration process, we can provide a broad array of solutions, through numerous geographic locations, with highly capable staff and cutting-edge technologies to address your needs and the challenges you face.

Though our name is changing, our commitment to our clients and their projects remains the same. Our people working with you will continue to work with you. Our goal remains to continue providing clients with high-quality, responsive service and to make this organisational change transparent to you as we move forward.

Some material contained within this document may refer to our previous name Faber Maunsell, but is also applicable to AECOM.

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Table of Contents

List of Tables and Figures

LIST OF TABLES

LIST OF FIGURES

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Executive Summary

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Executive Summary

The Department for Communities and Local Government Planning Policy Statement 25 (PPS25) entitled "Development and Flood Risk" outlines how flood risk issues should be addressed in regional planning guidance and Local Authorities' development plans.

AECOM, (formally Faber Maunsell), were commissioned by West Lindsey District Council in January 2007 to undertake a Strategic Flood Risk Assessment of West Lindsey based on a Brief issued by the District Council. The Brief, prepared by the District Council in partnership with the Environment Agency, consisted of two distinct components summarised as follows:

- To classify all land within the District of West Lindsey into four categories of actual flood risk corresponding numerically to the four flood risk zones defined in PPS 25.
- To produce an assessment of the actual flood risk for a number of study areas within the West Lindsey District.

The purpose of the Study was to provide a reference and policy document to inform the West Lindsey Local Development Framework and to ensure that the District Council meets its obligations under PPS 25. The results of this study will enable the Council to apply the Sequential Test and, where relevant, the Exception Test throughout the District.

As part of the study AECOM have carried out a general Flood Risk Assessment for the whole of West Lindsey and detailed Flood Risk Assessments for four specific study areas within the District where future for urban development is considered to be the most likely. In two of these study areas, Gainsborough and Bardney, breaches in the flood defences have been modelled using the 2D modelling package Tuflow and flood hazard maps detailing depths, velocities and extent of flooding as a result of a breach in the flood defences have been produced. When sufficient data becomes available for the Market Rasen study area additional 2D modelling of that area may be required.

The results of the general Flood Risk Assessment are presented in this Report as a set of ten 1/25,000 scale maps covering the whole of the District and showing the actual flood risk at any point in one of four probabilities of flood risk, taking into account the effect of the existing flood defences in reducing flood risk. West Lindsey's principal flood defences consist chiefly of earth embankments along the major watercourses within the District providing various standards of protection.

A separate Flood Risk Assessment was also presented for each of the four study areas nominated by the District Council. For each area the principal flood risk source was identified and the extent of each of the three flood risk categories within that area described in detail. The salient flood risk and drainage features of the four study areas are illustrated in a series of 1/10,000 scale maps.

The extent and potential costs of raising the standard of the defences to 1 in 100 years for fluvial rivers and 1 in 200 years for tidal rivers has also been assessed in this report. The total cost of undertaking this work has been estimated as about £24,000,000.

The project was carried out in collaboration with the Environment Agency's Anglian and Midland Regions and utilised detailed sewerage plans of urban areas in the District provided by Anglian Water and Severn Trent Water and the Strategic Flood Risk Assessment has been undertaken in line with the Environment Agency's guidance notes to local authorities. A draft of this Report was submitted to the Environment Agency for their comments and observations and, following discussion with the Environment Agency, mutually acceptable amendments have been incorporated into this Final Report which has also been the subject of a formal audit by the Environment Agency.

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Introduction

1 Introduction

1.1 AECOM, (formally Faber Maunsell), were appointed by West Lindsey District Council (WLDC) on 26th January 2007 to undertake a Strategic Flood Risk Assessment (SFRA) of the District of West Lindsey. The scope of the study was described in a Brief issued jointly by the District Council and the Environment Agency. A Location Plan showing the West Lindsey District is given in Figure 1.1.

1.2 The SFRA was intended to build upon the previous SFRA undertaken for the Lincoln Policy Area, which included parts of West Lindsey, but not the urban centres of Gainsborough and Market Rasen, and will have regard to the East Midlands Regional Flood Risk Appraisal and the North Lincolnshire and North East Lincolnshire Councils' SFRA.

1.3 The West Lindsey SRFA was to be undertaken in accordance with the Government guidance contained in PPS 25 and its accompanying Practice Guide Companion and the Environment Agency's Guidance for Local Planning Authorities. Due consideration has also been given to the Environment Agency's guidance notes on flood risk assessment issued to Local Planning Authorities.

1.4 Planning Policy Statement 25 ("PPS 25") (Ref 1) Draft issued in December 2006 by the Department of Communities and Local Government expects local planning authorities to apply a risk-based approach to the preparation of their development plans in respect of possible flooding. Annexe E of PPS 25 contains specific guidance for planning authorities and those working on their behalf on the methodology to be used in undertaking a flood risk assessment. PPS 25 and its implications are discussed in greater detail in the next Section.

1.5 The principle objectives of the study consist of two distinct components, summarised as follows:

a) To classify all land within the District of West Lindsey into four flood risk categories corresponding numerically to the four flood zones defined in PPS 25.

b) To produce an assessment of the actual flood risk for a number of study areas within the West Lindsey District.

1.6 To achieve the first objective the Environment Agency's Flood Maps and Flood Zone Maps (see Section 2) were used as a starting point. These maps, supplemented by other information supplied by the District Council, the Environment Agency, Anglian Water Services, Severn Trent Water, Internal Drainage Boards and other sources, were used to develop a series of ten 1/25,000 scale Strategic Flood Risk Maps which show all land classified in Flood Zones 1, 2 and 3 within West Lindsey.

1.7 This report uses the term Actual Flood Risk and this is used to indicate the probability of flooding to those areas of land that have some degree of protection from existing flood defences. The defences will not remove the risk of flooding completely and the standard of protection they provide will vary in different locations. The probability of flooding may therefore be considerably lower for an area behind existing defences than indicated by the PPS 25 flood zones, which ignore the presence of the existing defences.

1.8 To achieve the second objective, the District Council designated four study areas within West Lindsey which they consider may be at risk of flooding (based on information shown on the Environment Agency's Flood Maps) or where development could increase the risk of flooding elsewhere. These four areas are listed in Table 1.1 and their locations shown in Figures 1.2.1 to 1.2.4.

Study Area	Area (km^2)
Gainsborough	11.69
Market Rasen	4.46
Saxilby	2.11
Bardney	1.10

Table 1.1 – Study Areas in West Lindsey for Flood Risk Assessment.

1.9 For each of the four study areas the following have been investigated and described:

- General description of the study area
- Hydrology of the study area
- Flood risks within the study area
- Flood risk to downstream areas

The principal hydrological and drainage features affecting flood risk in each study area are shown on individual site plans.

1.10 For the Gainsborough and Bardney study areas flood hazard maps occurring as a result of a breach in the defences have been prepared. The results of the 2D modelling are presented as three 1:10 000 scale maps showing flood depth, velocity and flood hazard rating in each study area. This information will enable West Lindsey District Council to apply the sequential and exception test when allocating land for development.

1.11 Even though Market Rasen is a key area for future development, there are no up to date hydraulic models of the River Rase available at present which would enable accurate flood hazard mapping to be undertaken. Once the River Rase hydraulic model has been approved by the Environment Agency, the modelled results will need to be incorporated into this SFRA.

1.12 In Saxilby, there are no major land allocations for future development behind raised defences within the Flood Zones and thus no flood hazard modelling was required at this location.

1.13 In addition to this document reference should also be made to the Environment Agency's River Trent Catchment Flood Management Plan (CFMP).

1.14 This document has been prepared by AECOM Ltd ("AECOM") for sole use of the client entity detailed above (the "Client") in accordance with generally accepted consultancy principles and the budget for fees and the terms of reference agreed between AECOM and the Client. Any information provided by third parties and referred to herein has not been checked or verified by AECOM, unless otherwise expressly stated in this document. No third party may rely upon this document without the prior and express written agreement of AECOM.

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Level 1SFRA

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2 Level 1 SFRA

Planning Policy Statement 25

2.1 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 the LPA to understand the risk across its area so that the sequential test can be properly applied.

Sequential Test

2.2 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 Risk

2.3 Flood risk can arise from both fluvial and tidal sources. Fluvial flooding occurs 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. 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.

2.4 The majority of West Lindsey is subject to fluvial flooding with the exception of the River Trent which is subject to fluvial and tidal flooding. Flooding and flood risk considered in this Report therefore relates to both fluvial and tidal flooding.

Flood Zones

2.5 Planning Policy Statement 25 (PPS 25) defines four distinct zones of inherent flood risk. These zones are based on the quantified degree of flood risk to which an area of land is subject at the time at which a land allocation decision is made or a planning application submitted, but they take no account of existing flood defences. The PPS 25 flood zones and their associated fluvial and tidal flood risk characterisations are summarised in Table 2.1 below.

Zone	Probability	Assigned Annual Flood Probabilities
1	Low	Less than 0.1% (above 1 in 1000 years)
2	Medium	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	Fluvial - greater than 1% (under 1 in 100 years) Tidal – greater than 0.5% (under 1 in 200 years)
3b	Functional Floodplain	Greater than 5% (under 1 in 20 years) (Defined in PPS25 (Table D1) as “land where water has to flow or be stored in times of flood”.)

Table 2.1 - PPS 25 Flood Zones.

2.6 The PPS 25 Flood Zones provide a broad indication of inherent flood risk. Most areas which fall within the High Probability Zone (Zone 3a) are on fluvial floodplains although the risk of tidal flooding should not be overlooked. Many of these Zone 3a areas already enjoy some degree of protection from established flood defences. The presence of flood defences may significantly reduce the risk of flooding at the present time, but this protection is dependent upon the continued maintenance of those defences. The current level of flood risk may therefore be considerably lower for an area behind existing defences than implied by the PPS 25 classification. Hence the role of the SFRA is to evaluate the actual risk of flooding to development behind those defences.

2.7 PPS 25 requires Local Planning Authorities to adopt a risk-based approach to development in areas at risk of flooding, and to apply a sequential test to such areas. This means that, other factors being equal, the planning authority would favour development in areas with a lower flood risk. .

2.8 An exception test can also be applied after the 'sequential test' if there are no reasonably available development sites in Flood Zone 1 or 2. In exceptional circumstances, decision-makers can consider the suitability of sites in Flood Zone 3 by applying the 'exception test'. As the study areas within the PPS 25 "High Probability" zone may be at very different risks of flooding, the planning authority must be able to rank study areas according to actual flood risk For the exception test to be passed, it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh the flood risk, be on previously developed land, and a site-specific flood risk assessment (FRA) must demonstrate that the development will be safe, and not increase flood risk elsewhere.

2.9 PPS 25 also defines functional floodplains. These are "the unobstructed or active areas where water regularly flows in times of flood". A functional floodplain can also be either an area of floodplain which is known to flood frequently and where flooding is tolerated, as it may prevent or ameliorate flooding elsewhere, or an area within a floodplain that can be deliberately inundated during a flood event to provide temporary retention storage for flood water.

Indicative Floodplain Maps

2.10 Under Section 105 of the Water Resources Act 1991 the Environment Agency, having undertaken a nationwide study, produced a series of maps covering the whole of England and Wales ("Circular 30/92 Maps") showing areas of land considered to be at risk of fluvial and tidal flooding and the likely extent of that flooding. These maps were then used as the basis for the Environment Agency's Indicative Floodplain maps.

2.11 The criterion adopted by the Environment Agency to define those areas considered to be at risk of fluvial flooding was an annual probability of flooding of 1% or more (i.e. they could expect to have a 1% chance of flooding in any one year) or where flooding has been known to occur. The 1% annual probability criterion was numerically the same as that subsequently adopted for the PPS 25 "High Probability" Zone 3. Where the flood envelope of the highest recorded historical flood is more extensive than that of the 1% (100 year) flood, the former was shown on the Indicative Floodplain maps.

2.12 Indicative Floodplain (IF) maps, based on Ordnance Survey 1/10,000 scale base maps, were first issued in 2000. In 2001 the Environment Agency issued electronic versions of these maps to all Local Planning Authorities. The information was also placed in the public domain on the internet, albeit at a smaller (1/50,000) scale.

2.13 On the IF maps, floodplains were shown to extend up river and stream valleys only to the upstream limit of Main River or (in some Regions) where the catchment area above that point falls below 10 km^2. This arbitrary limit could sometimes result in the abrupt truncation of a floodplain and give the potentially misleading impression that significant flood risk ceases at the edge of the envelope shown on the map.

2.14 Although the IF maps represented an improvement on the Agency's previous mapping and used the best mapping techniques and information then available, the shape and extent of the floodplain shown on the IF maps could not be regarded as definitive. Detailed local studies of the floodplain sometimes revealed anomalies and inaccuracies in the position of the floodplain envelope as shown on the maps. The Environment Agency readily admitted that such anomalies would appear from time to time and indicated their willingness to modify the IF maps in such cases. The latest available version of the IF maps was issued by the Environment Agency in 2002.

Flood Zone Maps

2.15 Following a comprehensive tidal and fluvial flood risk mapping exercise carried out across the country, the Environment Agency issued a set of Flood Zone (FZ) Maps to each Local Planning Authority in England and Wales during Summer 2004 covering the whole of that authority's area in electronic format. The West Lindsey FZ Maps were made available to AECOM on CD by West Lindsey District Council. It is these maps that should be used initially for the application of the sequential test

2.16 The FZ maps were prepared using nationally consistent methodologies for the determination of flood zones for both tidal and fluvial flooding. Whereas the IF maps showed only the indicative floodplain, which corresponded generally to the then applicable Planning Policy Guidance Note (PPG 25) (Ref.2) Flood Risk Zone 3, the FZ maps show both PPG 25 Flood Risk Zones 2 and 3. The FZ maps also exclude the effect of existing flood defences, but go one step further than the IF maps in removing the effects of informal defences such as road and railway embankments, major artificial drainage channels etc. This is because such structures were not specifically designed to function as a flood defence.

2.17 The FZ maps, like the earlier IF maps, are based on OS 1/10,000 scale maps but, unlike the IF maps, the FZ maps are not limited to Main River floodplain but include the floodplain of all watercourses with a catchment area of more than 3 km^2.

2.18 Flood Zone maps are not readily accessible to the general public or those wishing to undertake detailed flood risk assessments. Those wishing to consult the FZ map for a specific area may do so through the relevant Local Planning Authority. In some cases the Environment Agency will provide excerpts from the FZ for specific localities but there is, as yet, no common policy as regards access to the maps, provision of copies of the maps, and charging for access / copies.

Flood Maps

2.19 In October 2004 the Environment Agency issued a further set of flood risk maps covering all of England and Wales. These maps, issued only at 1/50,000 scale, were intended for use by the general public and are available on the Agency's website. They were not intended, at this stage, to supersede the larger scale and more detailed FZ maps issued to Local Authorities but to be used in conjunction with them.

2.20 The Flood Maps show two flood risk zones; a 'dark blue' zone in which annual probabilities of flooding are defined as greater than 1% for fluvial flooding (>0.5% for tidal flooding) and a 'light blue' zone in which the annual probability is between 0.1% and 1% (0.5% tidal) corresponding to Flood Zones 3 and 2 respectively. Like the FZ maps, the Flood Maps show the potential extent of flooding without defences but, unlike the IF maps, the FZ and Flood Maps make no distinction between fluvial and tidal flood risk areas. Flood defences (and defended areas) are shown on the Flood Maps where those defences, at the time of the maps' publication, were less than five years old and gave a 1% (0.5% tidal) standard of protection.

2.21 Users of the Flood Maps are invited to "click on" to any point on the map for which a specific flood risk assessment is required. The user will then find the flood risk at that point categorised and defined as one of the following:

"Significant" annual probability >1.3% (once in less than 75 years)

"Moderate" annual probability between 1.3% and 0.5% (1 in 75 to 200 years)

"Low" annual probability less than 0.5% (1 in >200 years).

2.22 The 1.3% (1 in 75 years) annual probability level corresponds to the level currently adopted by the British Insurance Association and not that used in PPS 25.

2.23 Users of Flood Maps who "click on" to a point in a dark blue zone on the map may find the flood risk at that point classified as either "significant", "moderate" or even "low". This classification will be determined by the existence and standard of the flood defences at that point. Even where no defences are shown specifically on the map, their presence may sometimes be inferred from the flood risk categorisation given.

2.24 The Environment Agency now updates the Flood Maps on a three-monthly basis in order to ensure that the maps reflect the latest assessments of flood risk and to remove anomalies. At some locations, for example, it is possible to “click on” to a dark blue area on the map where no flood defences exist and where flooding is known to occur and obtain a “low” flood risk classification.

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Causes of Flooding

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3 Causes of Flooding

3.1 West Lindsey occupies the north-western corner of Lincolnshire. It is a large District covering an area of 1,156km^2 of predominately open countryside, much of which is arable land. The largest settlement is the market and industrial town of Gainsborough in the west of the District. In the eastern part of the District lie two smaller market towns, Market Rasen and Caistor, and adjoining the southern boundary of the District is the City of Lincoln.

3.2 West Lindsey has many rivers flowing through it or creating the boundary to the District. The River Trent forms the western boundary of the District and the River Witham the south east. The Barlings Eau originates north of Cold Hanworth (north east of Welton) and flows southerly joining the River Witham at Short Ferry. The Fossdyke Canal connects from Torksey on the River Trent to Lincoln with the River Till joining the canal downstream of Saxilby. The River Till originates at Corringham, east of Gainsborough and flows southerly towards Saxilby. The River Ancholme is situated towards the north of the District. It originates at West Firsby flowing generally north and feeding into the Humber Estuary. The River Rase originates in the Wolds and flows westerly joining the River Ancholme at Harlam Hill.

3.3 The principal features of the underlying geology are Jurassic Limestone of Lincoln Edge and chalk of the Lincolnshire Wolds. These and the Trent Valley and Vale of Ancholme have produced the landforms typical of the central English Midlands; broad, relatively flat river valleys separated by expanses of upland characterised by a rolling landscape of ridges and steeper, tributary stream valleys. Flooding in such areas can therefore occur two distinct ways, as described in the following sub-sections.

Overflowing of Watercourses

3.4 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.

3.5 With an upland river the adjoining land is its natural floodplain, which will generally be of limited extent and fairly well defined. In the fenlands the entire area, in theory, constitutes the "natural floodplain" of all the rivers that flow through it. In reality, centuries of fen drainage, flood defence and land reclamation works have rendered the concept of a ''natural floodplain'' for fenland rivers inapplicable. (In North Lincolnshire the fens are more usually known as "Carrs").

3.6 In the case of a major river, such as the River Trent, 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 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 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 the floodplain, often with steps taken to mitigate the associated risks of flooding.

3.7 75Within West Lindsey the River Trent and River Ancholme, for example, are major watercourses which are embanked above the level of the surrounding fenland. Overflowing of these high-level watercourses can become a serious problem where they are embanked above the level of the adjacent land, and they are therefore all maintained as "Main Rivers" by the Environment Agency.

3.8 From experience and observations when overtopping of an embanked watercourse occurs, the depth of water flowing over the flood wall or embankment will probably be small, a few centimetres at most. The bank will act like a weir and the rate of flow per unit length will be relatively modest and this, combined with the limited duration of the overtopping, will limit the volume of water cascading over the defences to cause flooding. If overtopping does occur and the protected area is of considerable extent, any flooding which results will often be disruptive rather than be 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 in paragraphs 3.11 to 3.15 below.

3.9 Some of the low-lying areas adjacent to the embanked rivers are pump-drained to those rivers. Along the River Trent in West Lindsey there are two land drainage pumping stations at Torksey, one at Trent Port, Marton, and another north of Gainsborough all of which pump-drain the surrounding low-lying land into the River Trent. On the River Witham, there are two pumping stations, one at Fiskerton, and the other at Short Ferry that drain the land adjacent to the River Witham and the Barlings Eau. On the River Ancholme, the two pumping stations on either side of the river at Brandy Wharf pump-drain the land to the west and east of the river. There are also numerous other pumping stations situated on the banks of the River Ancholme that pump drain the surrounding land. These include pumping stations at North Kelsey and South Kelsey.

3.10 These land drainage pumping stations and their associated network of unembanked drains are maintained by Internal Drainage Boards. If an unembanked pump-drained channel is overtopped, the overflow spreads slowly over a wide area and, with the exception of local low spots; the result is widespread waterlogging, rather than serious inundation.

Breaching of Embankments

3.11 An earth embankment may be breached as a direct result of overflowing. Overtopping of a 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 channel. 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. Complete collapse of the bank may take only minutes. The contents of the embanked channel then pour through the breach and across the surrounding land.

3.12 A tarmac road or dwarf flood wall 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. Conversely, the structural condition of a flood defence, its load capacity and its state of maintenance will all play a role in determining the possibility of a premature breach before overtopping occurs. Experience 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 40 metres. Unlike tidal defence flood banks, 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 flood banks along the same reach of river, thus considerably reducing the risk of further breaches in the same area.

3.13 The design of a flood bank (or flood wall) incorporates a certain level of freeboard to allow for uncertainties, for example bank settlement or wave action, 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 be 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. **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 that for which the embanked channel was designed.**

3.14 Apart from overtopping, breaches in flood banks 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 an exceptional hydraulic gradient through the bank arises during flood conditions, 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.

3.15 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

3.16 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.

3.17 Structural failure, in this context, is also taken to include the failure of "hard" defences in urban areas such as concrete flood walls. "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.

3.18 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. The Environment Agency is not aware of any sluices on Main Rivers in West Lindsey operated by anyone but themselves.

3.19 Flooding, especially that caused by overflowing of watercourses, can be exacerbated by other operational failures. These failures can 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.

3.20 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.

Localised Flooding

3.21 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.

3.22 Intense storm rainfall, particularly in urban areas, can create runoff conditions which temporarily overwhelm the capacity of the local sewer and drainage system to cope with the sudden deluge. Localised “flash” flooding then occurs. In upland areas with small, relatively steep, impermeable catchments, this may result in quite severe flooding over a limited area, often with a considerable depth and velocity of flood water. The duration of such flooding is usually relatively short but this does not mitigate its impact for those affected, especially when the flooding may have developed suddenly and unexpectedly.

3.23 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.

3.24 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.

3.25 In recent years some urban watercourses considered to be particularly at risk from such blockages have been designated "Critical Ordinary Watercourses" (COWs) although this designation never had 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 is currently in the process of adopting all COWs as Main River. Where a COW is at present separated from the Main River system by a length of non-Main River the intervening watercourse is also enmained. All COWs that existed in the West Lindsey District have been converted to Main Rivers.

3.26 In inland areas, all local surface water drainage systems discharge to a major stream or river. Except where pumps have been installed, this discharge is by gravity. If the receiving stream or river is in flood, especially where that watercourse is contained within raised flood walls or banks, the flow in the local drainage system can no longer drain to the river and is impounded behind the defence line for the duration of the flood. This is known as "floodlocking". This can result in secondary flooding within the defended area, even though the defences may not have been breached or overtopped. Fortunately, this secondary flooding is usually less severe or widespread than primary flooding from the main river would have been.

3.27 The occurrence of secondary flooding depends on the coincidence of heavy rain over the local drainage catchment with "floodlocking" of its outfall. In most instances, the rainfall event that caused the flood conditions in the river may also have caused high flows in the local drainage system but because of the much slower hydrological response of the river, the rapid runoff from the local catchment will have discharged to the river before the flood peak in the river arrives at the local drainage outfall.

3.28 Secondary flooding, where blockages or "floodlocking" is involved, depends upon what are either random events or a complex coincidence of events. Its probability of occurrence is therefore difficult to quantify and it falls within the category of "residual risk".

Tidal Flooding

3.29 In eastern England tidal flooding of coastal plains or land alongside tidal estuaries is caused by a combination of a North Sea storm surge and a lunar high tide. In coastal areas tidal flood risk is often exacerbated by the destructive effect of severe wave action on tidal defences but this complication will not occur in West Lindsey where tidal flood risk only exists along the sheltered tidal estuary of the River Trent. The particular case of estuarine flooding will be considered in more detail in Section 4.

Functional Floodplains and Washlands

3.30 Functional floodplains are defined in PPS 25 where they form the basis for Flood Zone 3b. A definition of functional floodplains has been given in paragraph 2.7.

3.31 Washlands are areas of land that have been designed to alleviate flooding by storing floodwater within man-made embankments under controlled conditions.

3.32 Flooding, whether controlled or uncontrolled, of functional floodplains and washlands can be expected to occur with a frequency of 5% (once in twenty years) or greater. The Environment Agency's River Till controlled washland, a substantial flood storage area to the north of Saxilby, into which flood flows in the river can be diverted when they reach a pre-determined level, clearly falls within this category. The washlands upstream of Market Rasen on the River Rase and the Beckingham Marshes washland just outside West Lindsey's boundary on the left bank of the River Trent adjacent to Gainsborough also falls within this category.

Other Sources of Flooding

3.33 Other potential sources of flooding identified in PPS25 include flooding from canals or reservoirs, from groundwater, flooding from sewers and surface water flooding. Each of these potential flood risk sources will be considered in the following paragraphs in the context of West Lindsey.

<u>Canals & Reservoirs</u>

3.34 The Fossdyke and Caistor Canals are the only canals in West Lindsey. The eastern end of the Fossdyke Canal is, in effect, the canalised downstream end of the River Till and has been assessed in that context. The western end of the Fossdyke is a backwater of the eastern end with no significant natural inflows and no significant sections of embanked channel and can therefore be discounted as a flood risk.

3.35 The Caistor Canal ceased to be used for navigation in the mid-nineteenth century and all the locks have been dismantled. It is now the canalised downstream end of the Nettleton Beck and for flood risk purposes can be considered as a minor fluvial flood risk source.

3.36 Apart from the Till and Rase Washlands which are only full for brief periods at infrequent intervals, the only large raised reservoir in West Lindsey is Toft Newton Reservoir, 7km west of Market Rasen. This modern bunded reservoir was constructed in 1972/3 as part of the Trent-Witham-Ancholme bulk raw water transfer scheme. It is situated in open country just upstream of the head of the canalised section of the River Ancholme. There is no natural inflow to the reservoir and it subject to the rigorous safety inspections required by the 1975 Reservoirs Act. This reservoir presents only a minimal residual risk to the sparsely populated fenland (carrs) along the Ancholme valley.

Flooding from Groundwater

3.37 Flooding from groundwater occurs predominantly in chalk areas where prolonged periods of heavy rainfall can result in very large fluctuations in groundwater levels. In extreme events ephemeral substantial springflow can appear in the base of dry valleys (bournes) where surface flow has not occurred for many years, during which time stream channels have become lost to agriculture or, even where small perennial flows occur, have been severely constricted by urban development.

3.38 The chalk ridge of the Lincolnshire Wolds comprises the north-eastern corner of West Lindsey. The scarp slope of the Wolds are fed by Spilsby Sandstone springs so the towns of Caistor and Market Rasen below the scarp slope are not at significant risk of groundwater (as opposed to fluvial) flooding. The only location where the risk of groundwater flooding is likely to arise is in the chalk bournes along the dip slope of the Wolds. Fortunately this is a sparsely populated area and there is very little development in the valley bottoms apart from small, old established villages such as Rothwell, Cuxwold and Swallow and isolated hamlets where development will have evolved over centuries to accommodate this type of flooding. Groundwater flooding can therefore be disregarded as a significant flood risk in West Lindsey.

Sewers and Surface Water Flooding

3.39 Surface water flooding caused by excess runoff from extensive impermeable areas created by development (roofs, paved areas, roadways etc) is essentially an urban phenomenon and does not occur in rural areas except where natural sub-soil flow paths have locally been obstructed by development.

3.40 Flooding as a result of the surcharging of combined flow or surface water sewers when runoff entering those sewers exceeds their hydraulic capacity is similarly an urban phenomenon. These types of flooding will therefore only be taken into account in the flood risk assessments of the four urban study areas nominated by the Council.

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Flooding in West Lindsey

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4 Flooding in West Lindsey

Classes of Flooding

4.1 Potential flooding in West Lindsey can be grouped into five general classes determined by the predominant landforms in the area. These classes are introduced to illustrate the topographical divisions in West Lindsey, putting the SFRA in context, and not to replace the PPS25 flood risk probability or vulnerability categories used in the sequential and exception tests. The five classes are outlined below:

Fenland – Class 1a

4.2 Flooding from embanked, high-level watercourses due to overtopping of the embankments. This type of flooding can extend over a wide area but will usually be fairly shallow and contained within well defined "flooding compartments" created by artificial embankments, (for example spoil banks, raised river or drain banks, roads, or railways) or the edge of higher land.

Fenland – Class 1b

4.3 Flooding from embanked high-level watercourses due to breaching of the embankments. This is identical in origin but invariably more serious than Class 1a flooding. Flood depths will be significantly greater and there may be a serious hazard to life and limb in the immediate vicinity of the breach.

Fenland – Class 2

4.4 This occurs within a pump-drained catchment when the capacity of the drainage network or its pumping station is exceeded by the runoff generated by the flood event. The resultant flooding will be confined to widespread waterlogging of land with drains at or just above bankfull conditions. As the fenland is nowhere completely level, extensive areas of shallow ponding may occur on the lowest land. This rarely affects settlements or farmsteads which, from historical experience, have been established on the marginally higher land.

Lowland Plains - Class 3

4.5 This type of flooding results from the overflowing of relatively large, slow moving rivers (and tributaries with which they are in hydraulic continuity) onto a wide, extensive floodplain. Flooding of this nature will vary in depth but arises from continuous, frontal rainfall, usually on an already saturated catchment, developing over a period of hours or even days. The duration of flooding will, however, be correspondingly prolonged. Away from the river itself the flood flow velocities are low. The land adjacent to the main river may, in certain places, be protected by flood banks but these will be of modest height and, even if breached, the consequences will be very much less severe than in fenland areas.

Upland River Valleys - Class 4a

4.6 Closer to their headwaters, rivers in these areas will be smaller but faster flowing. Flooding will occur by overtopping of the banks but as the valley, and hence its floodplain, is relatively narrow the flooded area will be of limited extent. Nevertheless, the depth of flooding may be considerable, especially where the river flow is impeded by obstructions. The velocity of the water over the floodplain may be considerable; although in the gentler topography of West Lindsey itself it is unlikely to reach "life and limb" hazard velocities encountered, for example, in steep, narrow Pennine valleys. This type of flooding is typically "flashier" than that experienced in Class 3 and, especially with smaller watercourses, arises from exceptionally heavy, but shorter duration and more intense rainstorms.

Upland River Valleys - Class 4b

4.7 This has the same origin as Class 4a flooding but occurs in urban areas where the watercourse has been extensively culverted, as described in paragraph 3.23.

Localised Flooding - Class 5a

4.8 In theory this results from a local urban drainage system being unable to cope with the rate of runoff from a particularly heavy, intense storm larger than that for which it was designed. In practice, the problem is usually exacerbated by an obstruction or blockage of the drainage system, either by a long term accumulation of silt or debris, or by larger debris carried along with the storm runoff. In such cases the flooding can occur almost at random, and on a relatively moderate storm event and hence comes under the heading of "residual risk" flooding in PPS 25. Unless the problem is chronic, due, for example, to under-design, once the obstruction has been removed the flood risk can be drastically reduced. This type of flooding is normally associated with the local surface water or combined (surface and foul) sewerage systems and its effects are generally limited to part of a street or small cluster of properties.

Localised Flooding - Class 5b

4.9 This occurs at the downstream end of small local drainage systems, either urban or rural, as the result of "floodlocking" of the local drainage outfall by flood levels in the river or watercourse into which the local system discharges. This has been described in some detail in paragraph 3.26.

Tidal Flooding

4.10 Tidal flooding can occur both as a result of overtopping or breaching of flood defences, or simply by encroachment of tidal waters onto adjacent land during an exceptionally high tide. Along the Trent Estuary, where the river channel is heavily embanked, tidal flooding will therefore occur as a particular type of flooding Classes 1a or 1b (Fenland) rather than Class 3 (Lowland Plains).

4.11 Within West Lindsey, Classes 1 and 2 flooding would also be associated with the River Ancholme Levels downstream of Bishopbridge and the River Trent downstream of Morton. Class 3 would be associated with the low lying areas along the River Trent upstream of Gainsborough, and along the River Witham. Class 4 flooding would occur in the upstream reaches of the River Rase in the Wolds. Class 5a flooding could occur almost anywhere within the urban areas but is most likely along the routes of large surface water sewers. There are very few areas in West Lindsey where Class 5b flooding is considered to be a significant or widespread risk.

Records of Flooding

4.12 West Lindsey District Council, the Environment Agency and Internal Drainage Boards were all contacted to obtain information on flooding records and drainage problems in the District. The responses received are summarised below.

WEST LINDSEY DISTRICT COUNCIL

4.13 The District Council do not hold records of previous flood events apart from local problems, for example garden flooding, that have been reported to them. These were not deemed significant at a strategic level of study.

4.14 In June 2007, numerous towns and villages throughout West Lindsey were affected by flooding. Table 4.1 overleaf shows the location areas affected by flooding and the source of that flooding as recorded or assumed by West Lindsey District Council.

Location	Number of Properties Affected	Potential Source of Flooding
Apley	1	Local ditches and runoff from fields
Bardney	14	Local ditches and runoff from fields
Blyton	19	Laughton Highland Drain, runoff from fields
Bransby	3	River Till, runoff from fields, failure of Bransby PS
Brattleby	2	Local drainage systems, runoff from fields
Burton	3	Local drainage systems, runoff from fields
Cammeringham	2	Local drainage systems, runoff from fields
Cherry Willingham	16	Local drainage systems, runoff from fields
Claxby	1	Local drainage ditches, runoff
Dunholme	2	Local drainage system, runoff from fields
Fillingham	2	Local drainage systems, runoff from fields
Fiskerton	4	Local ditches and runoff from fields
Friesthorpe	1	Local drainage ditches, runoff from fields
Gainsborough	28	Local drainage systems
Glentham	3	Seggimoor Beck, local drainage systems, runoff from fields and saturated ground
Glentworth	3	Local drainage systems, runoff from fields
Grasby	1	Local drainage systems, runoff from fields
Hackthorn	2	Local drainage ditches, runoff from fields
Hemswell	1	Local drainage systems, runoff from fields
Hemswell Cliff	18	Local drainage systems, runoff from fields
Holton-Le-Moor	2	Local drainage ditches, runoff from fields
Ingham	7	Local drainage systems, runoff from fields
Keelby	6	Local drainage systems, runoff from fields
Kettlethorpe	5	Local drainage systems, runoff from fields
Kexby	5	River Till, runoff from fields
Kirkby + Osgodby	2	Local drainage ditches, runoff from fields
Knaith Park	1	Runoff from fields
Langworth	16	Nettleham (Sudbrooke) Beck, local drainage system, runoff from fields
Laughton	1	Laughton Beck
Lea	1	Runoff from fields
Legsby	1	Local drainage system, runoff from fields
Market Rasen	24	River Rase, River Rase South Branch, local drainage systems, urban runoff
Marton	1	River Trent, local drainage system, runoff from fields
Middle Rasen	17	River Rase, Brimmer Beck, local drainage systems, urban runoff
Moortown	1	Nettleton Beck, local drainage systems, runoff from fields
Morton	3	Local drainage system, runoff from fields
Nettleham	23	Nettleham Beck, groundwater
Nettleton	3	Nettleton Beck, local drainage ditches, runoff from fields
Newball	3	Barlings Eau, local drainage system, runoff from fields
Newton-on-Trent	2	Local drainage system
North Greetwell	1	Local drainage system, runoff from fields
North Kelsey	2	Local drainage system, runoff from fields
Orford	1	Local drainage systems
Reepham	1	Local drainage systems, runoff from fields
Saxilby	32	Fossdyke Canal, local drainage system, runoff from fields

Table 4.1 – Flooded Areas and Sources of Flooding, June 2007.

Location	Number of Properties Affected	Potential Source of Flooding
Scampton	1	Local drainage systems, runoff from fields
Scothern	3	Scothern Beck, local drains, runoff from fields
Scotter	27	Dar Beck
Snitterby	2	Snitterby Beck, local drainage ditches, runoff from fields
Somerby	1	Local drainage systems
South Carlton	1	Local drainage systems, runoff from fields
South Owersby	1	Local drainage ditches, runoff from fields
Spital in the Street	4	Local drainage ditches, runoff from fields
Stainfield	2	Stainfield Beck, runoff from fields
Stow	3	River Till, runoff from fields
Stow Park	1	River Till, runoff from fields
Sturton by Stow	14	River Till, runoff from fields
Sudbrooke	3	Nettleham (Sudbrooke) Beck, local drainage system, runoff from fields
Tealby	2	River Rase, urban runoff
Thorpe Lane	1	Local drainage systems, runoff from fields
Torksey Lock	1	River Trent, Fossdyke Canal
Waddingham	14	Waddingham beck, local drainage systems, runoff
Welton Hill	1	Local drainage system, runoff from fields
West Rasen	6	River Rase, urban runoff
Wharton	1	Local drainage systems
Willingham by Stow	4	River Till, runoff from fields
Willoughton	2	Local drainage systems, runoff from fields

Table 4.1 – June 2007 Flooded Areas and Source of Flooding (Contd).

4.15 From Table 4.1 it can be seen that the impact of the June 2007 flood was felt throughout the whole of the District and arose from numerous potential sources.

ENVIRONMENT AGENCY

4.16 A GIS map layer was provided by the Environment Agency showing the extent of flooding in the West Lindsey District for numerous historical flood events. Figure 4.1 shows the extent of historical flooding.

4.17 In 1947 fluvial flooding from the River Trent caused extensive flooding throughout West Lindsey (Ref 3) including areas of Wildsworth, East Stockwith, Laughterton and Newton on Trent. There was overtopping of the Trent floodbank in the Torksey area causing parts of the village to be flooded but the Spalford Bank protecting a considerable area as far east as Lincoln held, despite it being thought very likely that it would breach. Opposite Gainsborough the Beckingham Marshes were inundated from the river before the peak of the high tide, filling the flood storage there prematurely and causing about two thousand houses in Gainsborough town to be flooded.

4.18 The Trent bank at Morton breached on Sunday 23rd March 1947, bringing relief to the flood levels in Gainsborough. The breach was 80m wide and afterwards it was found that the scour hole was up to 9m deep in places (15m at one point) and extended 75m inland (Ref 3). Figure 4 shows the extent of the Morton breach.

Figure 4.0 – Morton Corner Breach, March 1947.

4.19 In February 1977 flooding also occurred from the River Trent but no flood outline or any details were able to be provided by the Environment Agency.

4.20 In April 1981, the River Witham, Barlings Eau, River Rase, River Ancholme and Kettleby Beck near Brigg all overflowed and caused flooding to adjacent land.

4.21 In October 1993 the Barlings Eau caused flooding from upstream of Langworth to its downstream extent. The tributaries along the right bank of the River Eau also overtopped. The River Witham flooded from its north bank towards Ferry Road and the villages of Fiskerton and Cherry Willingham but only a small amount of property was affected.

4.22 In June 2000 the River Rase washland was flooded. This alleviated any further flooding downstream in Market Rasen.

4.23 In November 2000 the River Till Flood Storage Reservoir flooded containing the flows and minimising the flood risk downstream. During this event flooding from the River Trent occurred namely at Dunham Bridge and Gainsborough Road, Lea. The River Eau was also recorded to have caused flooding. The Environment Agency commented that the flood event in November 2000 was not mapped along the River Trent and the River Eau in the West Lindsey District. The mapping from the River Trent only extended as far as villages downstream of Nottingham.

4.24 In November 2002 the River Rase South Branch Flood Storage Reservoir was inundated with water alleviating flood risk downstream on the River Rase.

4.25 In June 2007 Langworth, Welton, Nettleham, Market Rasen, Middle Rasen, West Rasen, Waddingham (including Brandy Wharf), Saxilby, Sturton by Stow, Blyton and Scotter were all badly affected by fluvial flooding - see Table 4.1.

4.26 The Environment Agency's Anglian Region also provided a list of drainage incidents that had been reported in West Lindsey. Fifty-six incidents in West Lindsey have been reported since 2000. Thirty-six of these incidents were Main River issues and dealt with by the Agency, six were ordinary watercourse issues dealt with under their supervisory duty, and 15 were ordinary watercourse incidents passed to the District Council. Table 4.2 lists the location of the incidents dealt with by West Lindsey District Council.

Location	Drainage Problem	Date
Caistor	Surface water	30-08-01
East Torrington	Unconsented weir	29-11-01
Sturton by Stow	Unmaintained dyke	02-07-02
Ingham	Unmaintained dyke	24-04-03
Glentworth	Unmaintained dyke	25-04-03
Nettleham	Unconsented weir	09-12-02
Saxilby	Unmaintained ditch / dyke	28-08-02
Toft Newton	Unmaintained dykes	24-04-03
Moortown	Surface water	15-02-02
Market Rasen	Unmaintained dykes	20-11-01
Market Rasen	Unmaintained dykes	27-01-03
Saxilby	Infilling of watercourse	22-07-03
Glentham	Collapsed culvert	29-08-03
Market Rasen	Obstructing flow	28-08-03
Ingham	Surface Water	20-09-04
Saxilby	Infilling of watercourse	08-09-04
Welton	Surface water	06-12-04
Owmby by Spital	Surface water	20-04-05
Kirkby cum Osgodby	Bank damage	22-05-06
Spridlington	Surface water	18-08-06
Roxby High Street	Obstruction in watercourse	18-08-06

Table 4.2 – Recorded Drainage Incidents Since 2000.

4.27 It was noted by the Environment Agency that none of these drainage problems were still outstanding.

INTERNAL DRAINAGE BOARDS (IDBs)

Newark Area IDB

4.28 Newark Area IDB identified the following parishes within West Lindsey that are affected by flood waters: Knaith, Gate Burton, Marton, Stow Park, Torksey, Fenton, Laughterton, Kettlethorpe, and Newton on Trent. All of this land is pumped into the Trent through pumping stations at Torksey and Marton. No information on specific dates or the extent of flooding was provided or available.

4.29 It was noted by the Board that in November 2000 the pumping station at Marton failed causing flood water to rise to approximately 3.90m AOD. This caused parts of Marton, Brampton and Torksey parishes to be inundated with water. In addition, during this event, the level in the River Trent was considerably higher causing Sand Lane at Torksey to be closed.

4.30 The Board do have minor drainage issues at Fenton, Laughterton and Newton affecting local drainage but these do not cause major problems.

North East Lindsey IDB

4.31 The only area within West Lindsey that is controlled by North East Lindsey IDB is part of Keelby village. The Board note that there is no history of flooding or any drainage problems.

Gainsborough IDB

4.32 Gainsborough IDB stated that prior to events at the end of June 2007 there has not been any recent history of significant flooding in that part of West Lindsey that lies within the Board's District. During the event at the end of June 2007 many roads within the Board's District became impassable and land was flooded.

4.33 Gainsborough IDB does not consider any areas to have excessive drainage problems due to all of the drains being regularly maintained by the Board. The information regarding the details of the flood event in June 2007 are still being collected by the Board.

Ancholme IDB

4.34 Ancholme IDB has four records of major historical flooding within West Lindsey. These events occurred in July 1973, April 1981, October 1993, and November 2000.

July 1973

4.35 In 1973 a report (Ref 4) presenting the findings of interviews with farmers affected by the flooding, shows that about 448.9ha of land was flooded within West Lindsey. The areas affected included Waddingham Pumped Area, Atterby Beck, Norton Beck, Candley Beck Drain, North Kelsey Beck, North Kelsey Carrs and South Kelsey Pumped Area.

April 1981

4.36 In 1981, the majority of the Board's District was flooded or severely waterlogged due to 73.4mm of rainfall falling in 72 hours (24th-26th April recorded at Howsham rain gauge) on an already saturated catchment. The river level rose from 1.22mOD on 23rd April to 2.18m on 25th April continually rising and peaking at 2.71mOD on 27th April (Ref 5). It is noted by the Board that the event was 1 in 65 years.

4.37 A breach on the left bank of the River Ancholme just upstream of Brandy Wharf Bridge on 26th April caused substantial flooding of agricultural land and some farm properties. Two breaches also occurred on the right bank of Sallow Row Drain on 26th April and one on the left bank of North Kelsey Beck on 27th April.

4.38 The worse affected areas were Candley Beck West Area due to overtopping of Kettleby Beck, North Kelsey Pumped Area due to the breach in North Kelsey Beck, Waddingham Pumped Area due to the breaches on the River Ancholme and Sallow Row Drain, and South Kelsey Pumped Area due to overtopping of the River Ancholme. Figure 4.2 shows the extent of flooding.

4.39 The gravity drained area of West Rasen, Middle Rasen and Market Rasen suffered extensive flooding as a result of 132mm of rainfall in approximately 70 hours. Substantial overtopping of the River Rase occurred on 26th April resulting in 120 houses and some industrial premises being flooded in Market Rasen and Middle Rasen. The main problems areas were in the vicinity of De Aston School and Willingham Road, at the junction of the River Rase and River Rase South Branch, along Pasture Lane and Waterloo Street and Jameson Bridge Street.

4.40 In Middle Rasen, Low Church Road, North Street, Church Street, Naylor's Drive and Abbot Close were the main problem areas. Downstream of Middle Rasen an occupation bridge was washed out by the force of the water. Minor overtopping in West Rasen also took place.

October 1993

4.41 In a report (Ref 6) written by the Board documenting the October 1993 flood event, it states that at Brigg rain gauge a total of 58mm of rainfall over three days was recorded. Over the same period, 91mm of rainfall was recorded from an Environment Agency rain gauge at Bishopsbridge. The level in the River Ancholme rose from 1.27mOD on 10th October to a peak of 2.8mOD on 13th October. The event was considered to be 1 in 50 years by the Board.

4.42 The worst affected areas were Bentley Farm area due to overtopping of the River Ancholme at Cadney Road, Waddingham Pumped Area, North Kelsey Pumped Area, and South Kelsey Pumped Area due to severe overtopping of the River Ancholme north and south of South Kelsey Pumping Station and the Rasens due to overtopping of the River Rase. The Rasens were the first to suffer with flooding of roads, property, and agricultural land.

November 2000

4.43 The flood event in November 2000 caused isolated parts of the Ancholme catchment to be inundated with water, as shown in Figure 4.2. A 0.5km^2 area on the right bank of the River Ancholme extending from downstream of Brandy Wharf was affected by flooding. Two areas from the right bank of Kelsey Beck, one at its downstream extent and the other north of Sadney Farm, were inundated with water as well as the Old River Ancholme along Cadney Road, south of Brigg.

June 2007

4.44 Recently, in June 2007, the majority of the River Ancholme catchment was affected by flood water. The Board are still, at present, gathering and processing the details of the flooded areas but they stated that the level in the River Ancholme was about 2.7m causing numerous sections of the bank to overtop. Two breaches also occurred, one in the Waddingham area and one in the South Kelsey Area of West Lindsey.

4.45 In Middle and West Rasen, there were large depths of water. In some places it was commented by the Board that the level was as high as a Landrovers bonnet.

Upper Witham IDB

4.46 Upper Witham IDB have been unable to provide details regarding historical flood events and drainage problems within the Boards District due to the recent flood events in June/July 2007. It was stated that the recent event had confirmed the Environment Agency's flood maps within their District and that the River Till flooded its natural floodplain from Tillbridge Lane upstream to Upton.

Witham 1st and 3rd District IDBs

4.47 A report by Anglian Water Authority's Lincolnshire River Division (Ref 7) documents the flooding during the 1981 event. The peak runoff in the Barlings Eau was severely in excess of its design capacity resulting in serious overtopping and breaching. One breach occurred on the left bank of the Barlings Eau upstream of Short Ferry Bridge which resulted in a large (pumped) area of Stainfield Fen being flooded. A further breach occurred on the right bank downstream of Barlings Abbey and this resulted in the flooding of a large (pumped) area of Fiskerton Fen, Willingham Fen and Greetwell Fen. A total of 1700 hectares was flooded.

4.48 On the remainder of the Barlings Eau and tributaries, overflowing of the channels caused a further 1200 hectares of land to be flooded. At Stainfield village, Stainfield Beck overflowed flooding 4 houses and the village school. At Langworth backing up of Nettleham Beck from the Barlings Eau resulted in 3 houses being flooded.

4.49 During this event the flood storage reservoir in Branston Island was also flooded to relieve the water levels in the Lower Witham. The breaches on the Barlings Eau also helped.

4.50 In a report (Ref 8) written by the Board, it describes many areas in West Lindsey in the Board's District that were inundated with water during the October 1993 flood event. The most severely affected areas were Sudbrooke, Snarford, Scothern, Freisthorpe, Snelland, and Wickenby due to the tributaries of the Barlings Eau being unable to discharge into the river causing the water in the tributaries to rise.

4.51 During the event, the Barlings Eau breached at Short Ferry on the right bank upstream of the pumping station. Flood water gushed into the IDB District causing Wheatmans Drain and Engine Drain to be overloaded. An extensive area of agricultural land was thus flooded as well as properties at Stainfield and Langworth.

4.52 The majority of floodwaters backed up in a northerly direction into Barlings Fen area. However substantial volumes of water flowed through the Engine Drain culvert and a disused high level culvert under the Fiskerton to Bardney road into Fiskerton Fen causing 403 hectares of land to be inundated with water.

Flood Alleviation Measures

4.53 Flood alleviation works fall into two broad categories. The first of these attenuates flood flows by the temporary storage of flood water in reservoirs upstream of the area at risk of flooding, thereby reducing peak flows in the river where it passes through the flood prone area. The second category increases the capacity of the river channel through the flood risk area to accommodate the unattenuated flood peak, usually by a combination of channel improvement whilst at the same time confining the river within raised flood walls or embankments. The flood alleviation works in West Lindsey fall into these two categories.

Gainsborough Flood Alleviation Scheme

4.54 Following flooding in 1947 a flood relief scheme was implemented in Gainsborough. The scheme consisted of a flood defence wall on the right bank of the River Trent for a distance of 2.4km at Gainsborough.

4.55 These defences were continually repaired and raised until, in 1990, a study was undertaken which concluded that the defences needed replacing. In response, a new flood defence scheme consisting of sheet piling and a 5m wide piled walkway extending into the river was constructed in phases between 1996 and 1999.

4.56 These defences were designed for the 1 in 200 year level plus freeboard, based on predicted still water levels for the year 2045. The 1 in 200 year water level in 2000 was estimated as 6.05mAOD and in the year 2045 as 6.5mAOD (Ref 9). The new defence height is 6.8mAOD providing a freeboard of 300mm.

4.57 These defences are critical to the protection of Gainsborough during flood events. If a defence were to fail, areas of Gainsborough in vicinity of the failure would be inundated with water.

4.58 The effect of the Gainsborough flood defences is to confine the river within fixed limits and prevent flood water from flowing across the narrow floodplain within the town. The inevitable loss of a relatively limited volume of urban floodplain and hence flood storage through Gainsborough as a consequence of the flood alleviation scheme must result in marginally increased flood peak flows, and thus marginally increased flood risk along the River Trent downstream. However, as the entire length of the River Trent is protected by some form of defence throughout West Lindsey, see paragraphs 4.63 to 4.66, the increased flood risk is minimal.

4.59 At present the Environment Agency are undertaking flood defence improvements to increase the level of flood protection offered to 2,600 properties in Gainsborough (Ref 10). The work stretches for 4km from Morton Corner in the north to the Trent railway bridge south of Gainsborough.

4.60 From Morton Corner to Bowling Green Lane and from Carr Lane to the railway bridge, the earth embankments are being strengthened by installing plastic cut-off walls inside the embankments. In some limited areas the height of the embankments is being increased to bring each reach up to the same standard of protection.

4.61 From Bowling Green Road to Carr Lane where there are existing flood walls and constraints on available land, ground anchors will be installed to strengthen the defences. These anchors are steel cables that are inserted through the riverside face of the existing sheet pile walls and then tied into the ground behind. The anchors will strengthen the existing defences without constricting the river channel. A rock blanket to protect flood walls from bank erosion will also be placed along the base of the defences.

4.62 At Carr Lane it is also proposed to construct a fifty metre section of new sheet pile flood wall in front of the existing concrete wall.

River Trent Flood Alleviation Works

4.63 Earth embankments have been constructed along the entire length of the River Trent in rural West Lindsey. Downstream of Gainsborough these defences have an average standard of protection of greater than a 200 year flood return period event (Ref 11). Upstream of Gainsborough the standard of protection ranges from less than two years to greater than 200 years. The embankments and flood walls have been designed to give a higher standard of protection in the urban areas.

4.64 The maintenance of these embankments is crucial in order to protect the urban areas and to control flood risk elsewhere in West Lindsey.

4.65 Some of these embankments have been designed with locally lower crest levels, for example at Lea Marshes, enabling flood water to inundate adjacent land, in extreme events and thus reducing the volume of water flowing downstream.

4.66 Beckingham Marshes on the left bank of the River Trent at Gainsborough are periodically used for flood storage in order to reduce flood risk and alleviate flooding in Gainsborough. The flood storage area covers approximately 488 hectares and was originally rich wet grassland but is now used for arable farming.

River Till Flood Alleviation Works

4.67 Earth embankments have been constructed along the River Till from Stow Road Bridge to its downstream extent. The embankments aid in increasing the capacity of the channel and confining flood water within the river channel.

4.68 In June 2007 the River Till flooded its natural floodplain from Upton downstream to Till Bridge Lane (A1500). It is not known if this created any significant problems in the affected area.

River Till Controlled Washland

4.69 In 1977, following flooding in 1947 and 1958 in the Lincoln Policy Area, feasibility studies were undertaken to investigate the flood risk in Lincoln. As a result, a scheme was implemented between 1984 and 1990 which consisted of two controlled washlands being constructed upstream of Lincoln; one at the confluence of the River Witham and River Brant (not in the West Lindsey District), and the other on the River Till near Saxilby (7km to the north west of Lincoln). These were designed primarily to provide protection to Lincoln.

4.70 The two washlands can store up to 9.5 million cubic metres of water altogether providing protection against a 1 in 100 year flood event (Ref 12).

4.71 The River Till washland consists of a shallow clay embankment across the valley with a control sluice on the river itself and one or more sets of inlet and outlet sluices in the river embankments.

4.72 The main purpose of the washland is to prevent any further rise in river level which could otherwise lead to overtopping of the defences downstream. When river levels reach predefined thresholds, controlled sluices are opened to take water into the washland flooding agricultural land. This restricts the volume of water passing through Lincoln. Once the peak of the flood has passed, water is released slowly back into the river system.

4.73 The washland was first used in November 2000 when heavy and prolonged rainfall caused flooding in many parts of the country. Successful operation of the washlands ensured that water levels in Lincoln were managed safely.

4.74 The building of the washland does reduce the flood risk in Lincoln if the flood event is less than 1 in 100 years. The washland, however, cannot prevent surface water drainage flooding in Lincoln due to localised heavy rainfall or major fluvial flooding from events with a return period greatly in excess of 100 years.

Lower Witham Flood Alleviation Scheme

4.75 In the 1990's the Environment Agency completed a strategy study for the Lower Witham between Lincoln and Boston which concluded that some of the flood embankments along the Witham were in a poor condition (Ref 13).

4.76 A phased programme incorporating the stabilisation of weaker lengths of the banks was adopted to provide a minimum flood defence standard of 1 in 10 years downstream of Lincoln.

4.77 The most vulnerable riverbanks were improved before the main River Witham works contract was awarded. These works were undertaken on the River Witham near Fiskerton and on the Barlings Eau at Short Ferry. The works involved raising and strengthening the embankments, placing rock erosion protection at the toe of the embankment and creating wet berms and fish refuges.

4.78 In total, 54 sites between Lincoln and Boston were identified for various degrees of stabilisation and protection works. Fourteen of these sites are located within the District of West Lindsey. These works comprised embankment raising and profiling, berm reinstatement works, seepage prevention works, toe erosion protection, and appropriate environmental enhancement. These works reduce the flood risk from the River Witham and Barlings Eau up to a 1 in 10 years flood return event. Maintenance of the embankments is crucial in minimising the flood risk from the River Witham.

River Rase Controlled Washlands Flood Alleviation Scheme

4.79 Following flooding in 1993, the Environment Agency considered various options to improve the flood defence standard of the River Rase through the urban areas of the Rasens. The preferred solution from the study was two storage areas upstream of Market Rasen; one on the River Rase and the other on the River Rase South Branch.

4.80 The primary objective of the scheme was to control the river flows passing through the urban areas of Market and Middle Rasen so that they were retained within the existing river channel. During times of flood, this is achieved by storing excess flood water in each of the two reservoirs and later releasing the water at a controlled rate. This method reduces the peak flow and results in the risk of flooding being reduced from a frequency of 1 in 10 years to 1 in 75 years.

4.81 The flood storage reservoir on the River Rase provides a design storage capacity of 90,000m^3 (Ref 14). Inlet and outlet control structures were specifically designed to optimise the amount of water which passes safely down the river and those stored in the reservoir. As upstream river levels rise, water flows automatically over a spillway at the inlet to the reservoir. Flow out of the reservoir is restricted by the size of the outfall culvert, which holds back the excess water filling the reservoir as the flow increases. Once the flood has passed, the water is gradually released back into the river.

4.82 The benefit of the system is that it is designed to operate automatically without the need for attendance at the site. A telemetry system continuously monitors river and reservoir levels.

4.83 The flood storage reservoir on the South Branch takes advantage of the natural valley contours. An earth embankment, formed from the surplus material at the River Rase Reservoir site, holds back the floodwater by a throttle control structure through the reservoir embankment, up to a design capacity of 121,000m^3 volume (Ref 14). As upstream flood flows increase, water backs up towards and onto the golf course. Only the restricted flow will pass safely downstream to the urban areas.

Operational and Emergency Planning

4.84 The West Lindsey District lies within the Environment Agency's Anglian and Midland Regions. In both of these regions 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.

4.85 Serious flooding in West Lindsey could trigger the declaration of a major incident. Should a major incident be declared, the West Lindsey District Council (WLDC)'s Emergency Plan would be energised.

4.86 The WLDC's Emergency Plan may be found on the Council's website, www.west-lindsey.gov.uk . Advice on action to be taken in the event of flooding may also be found on this website.

4.87 Specific responsibilities and actions by the Environment Agency, and 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 the West Lindsey Council Area'.

c) WLDC's 'Emergency Flood Response Plan'.

4.88 Parts of West Lindsey lie within the Environment Agency's flood warning areas, as shown in Figure 4.3. The Environment Agency issue flood warnings to these areas by a variety of methods including: Flood Warnings Direct; the national Floodline dial and listen telephone system; the internet; the media; flood wardens; and the AA roadwatch.

Climate Change

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5 Climate Change

5.1 As mentioned in Section 2, the flood envelopes which appear on the Environment Agency's Flood Zones 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. There are no published 'with climate change' equivalents of the FZs.

5.2 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 Flood Zone 2 envelope as an indication of the possible extent of Flood Zone 3 in 100 years time given the current predictions for climate change as identified on figure 5.1. This assumption is made on the basis that some broad-scale modelling, including topographical analysis, has been undertaken to produce the current FZ 2 outline, although not specifically to indentify future extent of FZ 3.

5.3 However, as no such modelling or analysis has been undertaken beyond the current FZ 2, it is not possible to produce similar maps for a possible extent of FZ 2 with 100 years of climate change and the planning authority should consider any proposed land allocation currently in FZ 1, which is adjacent to the extent of the current FZ 2, as having the potential to be within FZ 2 in the future.

5.4 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. Climate change is unlikely to have any significant impact on the velocity, depth or extent of the hazard zone.

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Sequential Test

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6 Sequential Test

6.1 PPS 25 states that the risk-based Sequential Test should be applied at all stages of planning and the Flood Zones are the starting point for the sequential approach. Where there are no reasonably available sites in Flood Zone 1 decision makers allocating land in spatial plans should take into account the flood risk vulnerability of land uses and consider sites in Flood Zone 2. Only where there are no sites available in Flood Zones 1 and 2 should they consider the suitability of sites in Flood Zone 3, applying the exception test if required.

6.2 West Lindsey will apply the sequential test, using the Environment Agency Flood Zones, to inform their future Local Development Documents in relation to future land allocations.

6.3 However, West Lindsey's current growth aspirations are focused on Gainsborough, Market Rasen, Saxilby and Bardney and the sequential test needs to be applied to these locations as follows.

Gainsborough

6.4 The western part of the existing developed area is within Flood Zone 3 and 2 arising from the River Trent where further development, particularly brownfield redevelopment, is likely to take place.

6.5 Further expansion in this area would be into Flood Zone 3 and 2 and the Exception Test would need to be applied.

Market Rasen

6.6 A narrow strip of Flood Zone 3 and 2 runs through the centre of the existing developed area arising from the River Rase.

6.7 Further development should be within Flood Zone 1

Saxilby

6.8 A small area of the existing development to the south west of the village is within Flood Zone 3 and 2.

6.9 Further development should be within Flood Zone 1

Bardney

6.10 The existing residential area is within Flood zone 1. However the existing sugar beet factory is adjacent to the River Witham and within Flood Zone 3 and 2.

6.11 Redevelopment of the sugar beet factory will be within Flood Zone 3 and 2 and the Exception Test would need to be applied.

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Exception Test

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7 Exception Test

7.1 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.

7.2 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 DPD 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 FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

7.3 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

7.4 The four areas identified by WLDC for their current growth aspirations have an area of Flood Zone 3 and 2 where future development could take place as follows:

Gainsborough

7.5 Any further development in the western part will take place in Flood Zones 3 and 2 and a detailed analysis of the actual flood risk and hazard zones has been undertaken as part of this study.

Bardney

7.6 Any redevelopment of the existing sugar beet factory will be within Flood Zone 3 and 2 and a detailed analysis of the actual flood risk and hazard zones has been undertaken as part of this study.

Saxilby

7.7 The majority of the existing development is within Flood Zone 1, however small scale planning applications might be received by WLDC for sites within Flood Zone 3 and 2 and an analysis of the actual flood risk has been undertaken as part of this study.

Market Rasen

7.8 The majority of the existing development is within Flood Zone 1, however small scale planning applications might be received by WLDC for sites within Flood Zone 3 and 2 and an analysis of the actual flood risk has been undertaken as part of this study.

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Level 2 SFRA

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8 Level 2 SFRA

Planning Policy Statement 25

8.1 PPS25 states that where the level 1 SFRA demonstrates that land in Flood Zone 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.

8.2 The PPS25 Flood Zones 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

8.3 However, areas within the High Probability Zone (Flood Zone 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. The actual degree of flood risk to which these areas are subject may well be significantly less than that implied by their PPS25 Flood Zone, provided that those defences are maintained at their current standard of protection.

8.4 Potential development areas in different parts of Flood Zone 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 Flood Zone 3.

8.5 In order to apply the sequential approach to areas within the Flood Zones the West Lindsey District Council will need to rank development according to actual flood risk.

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

8.7 To give full benefit to the Districts Council's planners, any assessment of flood risk within the study areas identified as being possible locations for potential development should, if possible, provide an evaluation of actual flood risk over the whole of those study areas. 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 Flood Zones 2 and 3 in accordance with their respective degree of actual flood risk.

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Actual Flood Risk

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9 Actual Flood Risk

Definition of Actual Flood risk

9.1 This report uses the term Actual Flood Risk and this is used to indicate the probability of flooding to those areas of land that have some degree of protection from existing flood defences. The defences will not remove the risk of flooding completely and the standard of protection they provide will vary in different locations. The probability of flooding may therefore be considerably lower for an area behind existing defences than indicated by the PPS 25 flood zones, which ignore the presence of the existing defences.

9.2 In order to be able to apply the sequential approach it is necessary to identify the different levels of actual flood risk, taking defences into account, and the following **Flood Risk Categories,** (Table 9.1) have been used to identify this actual flood risk.

9.3 As Zone 3 is now sub-divided into two components in PPS25, Zone 3a (annual probability <5%) and Zone 3b – the Functional Floodplain (annual probability >5%) it has been sub divided as follows.

Flood Risk Catogory	Range	
	Return Period	Annual Prob.
Category 1	>1000 yrs	<0.1%
Category 2	100 to 1000 yrs 200 to 1000 yrs	1% to 0.1% 0.5% to 0.1%
Category 3a	20 to 100 yrs 20 to 200 yrs	5% to 1% 5% to 0.5%
Category 3b	< 20 yrs	> 5%

Table 9.1 - Flood Risk Categories

9.4 These categories should enable an appropriate planning response to be made in individual cases, matching the nature of the proposed development with the relevant degree of actual flood risk within Flood Zone 3.

9.5 It must be noted that a flood risk category does not replace the flood zone when considering the vulnerability of the proposed development.

General Methodology

9.6 For the purposes of this study, the quantitative limits of the flood risk categories used will correspond exactly with the four flood zones defined in PPS 25 (Table 2.1 in this report). Since the Environment Agency's Flood Zone (FZ) maps represent an important initial attempt to define the limit of PPS 25 Flood Zones 2 and 3 (and hence the boundary between PPS 25 Flood Zones 1 and 2) they will be used as the basis for the detailed strategic (i.e. District-wide) assessment of flood risk within West Lindsey.

9.7 A previous study (Ref 15) has shown that although they were generally accurate and reliable, close inspection of the Environment Agency's earlier Indicative Floodplain (IF) maps revealed various anomalies in the plotting of the flood envelope. These anomalies were grouped into six types, as follows :

1) Where the flood level on one side of a floodplain was significantly different from that on the other.

2) Where the flood envelope did not follow a closely adjacent contour line where "ponded" flooding was known or could be assumed to occur.

3) Where the edge of the flood envelope indicated that the flood level at a point downstream was higher than the level a significant distance upstream.

4) Where the presence of an "island" in the floodplain had not been identified.

5) Where the water level gradient implied by the flood envelope boundary was clearly at variance with the general land level gradient along the valley floor in that area, except where due to an obvious obstruction to flow.

6) Where the presence of an obvious obstruction to overbank or channel flows (artificial embankment, restricted waterway at bridge, etc) had been ignored.

9.8 The Environment Agency's FZ maps were compiled using a different and more systematic methodology than their predecessor IF maps. It is confidently hoped that the anomalies identified with the IF maps have been eliminated, although a detailed investigation, outside the scope of this study, would be needed to confirm this. It should, however, be noted that the sixth anomaly listed above is no longer relevant in the context of FZ maps in which the impact of all such artificial obstructions has been removed. These anomalies are, nevertheless, presented here as they give an indication of potential errors applicable to all forms of flood risk mapping. As with all flood mapping, the accuracy of the floodplain envelope is dependent upon the precision of the ground survey data.

9.9 A number of sources of data and information are available which can be used to check and, where necessary, refine the Environment Agency's FZ maps and thus the outer limits of the High and Medium Probability zones (Zones 3 & 2). These are:

<u>LiDAR data</u>

The Environment Agency has established a national database of topographical spot-level data derived from an airborne laser imaging process. Contoured plots of Light Detecting and Ranging (LiDAR) data are found to be of greatest use in open country as the presence of buildings is found to give rise to clearly anomalous results in built-up areas.

At present the LiDAR data coverage does not extend over the whole country. There is LiDAR coverage of the West Lindsey District but this is at present limited to the fringes of the major rivers.

<u>SAR data</u>

The Ordnance Survey maintains a national database of Synthetic Aperture Radar (SAR) digital terrain model data. SAR data is obtained from survey aircraft or earth observation satellites. It is, however, less accurate than LiDAR data, with a vertical resolution of only $\pm$ 0.5m and a 5m horizontal grid. Not only is SAR data often found to be vertically shifted compared to the LiDAR data but the amount of the shift is not constant and varies with location. SAR data can be used to supplement LiDAR data but its inferior characteristics make achieving a smooth transition between LiDAR and SAR ground level data a challenge.

<u>Ordnance Survey Maps</u>

1/25,000 scale OS maps are contoured at 5m intervals which is adequate to give a general indication of the shape of the floodplain at any location. The contours are supplemented by spot heights to the nearest 1m on roads. It should, however, be noted that road levels can, particularly in floodplains, be significantly higher than adjacent land levels. A complete 1/25,000 scale OS map coverage of West Lindsey has been provided by West Lindsey DC.

A complete 1/50,000 scale OS map coverage of West Lindsey has also been provided by the District Council on CD which can be accessed using "MapInfo" software.

Flood Zone Maps and Flood Maps

The Environment Agency's Flood Zone Maps are based on OS 1/10,000 scale maps, and they show both Flood Zones 2 and 3 and, by inference, Zone 1. Copies of the FZ maps for the whole of West Lindsey were supplied to AECOM on CD.

The Environment Agency's Flood Maps are only available from the Environment Agency's website, and are based on an OS 1/50,000 scale map base. The representation of some recent flood defences (and, by inference, the presence of others) is useful but the small scale of these maps is a considerable drawback to their use, even at a strategic level. Isolated instances have already been found where the textual flood risk information obtained from Flood Maps for a fixed point by the "click-on" procedure is at variance with that shown graphically on the map for the same point.

Flooding Records

Records of past flooding, where available, (see Section 4) can be used to verify or amend the floodplain envelope.

9.10 In order to define the extent of all four actual flood risk categories (corresponding numerically to the PPS 25 flood zones) it is necessary only to delineate the boundaries between Categories 2 and 3 and between Categories 1 and 2 - i.e. the 1% (1 in 100 year) and 0.1% (1 in 1000 year) fluvial flood envelopes or the 0.5% (1 in 200 year) tidal flood envelope. The delineation of a more accurate 1% line by the identification and removal of local anomalies in the FZ maps has been outlined above, but the delineation of the 0.1% line presents more of a problem.

9.11 Research has demonstrated that the channel capacity of a natural river or stream is approximately equivalent to the mean annual flood flow which can be shown statistically to have a return period of $2^1/_3$ years (Ref 16). In other words, the natural river channel will start to spill over onto its floodplain nearly every other year. It is therefore reasonable to assume that there will also be a natural return period at which the floodplain is completely covered.

9.12 If a 1 in 1000 year flood were to occur there is no precise means of determining whether it was the 1 in 1000 year flood, rather than (say) a 1 in 500 year or a 1 in 10,000 year flood. In an area of sedimentary rocks, such as Lincolnshire, which was glaciated during the ice ages, the landforms are relatively recent. Since the last ice age there will, on the balance of probabilities, only have been a single 10,000 year flood and about a dozen floods in the 1000 to 5000 year return period range. It is therefore reasonable to assume that the fluvial floodplains have, since the ice ages, been shaped by a relatively small number of floods with return periods not greatly in excess of 1000 years. This suggests that the 1000 year flood would cover the entire floodplain but not to such a depth that the floodplain would be radically reshaped. Conversely, the outer limit of the floodplain, where it is clearly identifiable, roughly defines the 1000 year (0.1%) flood envelope.

9.13 Since there is often a marked discontinuity in ground slope between the floodplain and the land on either side, it is quite likely that in many places the 1000 year flood envelope is not significantly wider than the 100 year flood envelope. The respective depths of flooding over the floodplain could, of course, be significantly different.

9.14 In the areas of West Lindsey where no hydraulic models of the watercourses exist, the Environment Agency's FZ maps have been used as the basis for determining the flood risk categories. They have been studied in detail for any anomalies of the six types listed in para.5.2 above and in conjunction with the data sources described in para.5.4. Any obvious anomalies identified have been corrected and the 1 in 100 year and 1 in 1000 year flood envelopes amended accordingly.

9.15 Where hydraulic models of the watercourses exist the model results have been used to determine the flood risk categories. A description of the models and the process used to determine the flood extent is described in more detail later in this Section.

9.16 This process has resulted in the production of the set of ten 1/25,000 scale strategic flood risk maps of West Lindsey included as Figure 9.1 in this report.

Topographic Divisions

9.17 West Lindsey can be divided into three clearly defined topographic divisions. These three divisions are described in greater detail below.

FENLAND AREAS

9.18 The fenland area is confined to the River Trent Levels downstream of Gainsborough and the River Ancholme Levels downstream of Bishopbridge. In the north of Lincolnshire fens are more commonly known as Carrs. Fenland areas are often pump-drained.

9.19 In other topographical areas, the methodology outlined in para.5.7 could be used to add an estimate of the 1 in 1000 year flood envelope to the flood risk maps. However, in the fens there are no clearly defined floodplains, as are found in river valleys, and the methodology for identifying the boundary between Flood Risk Categories 1 and 2 outlined above cannot be applied in this case. The assumption that the larger settlements of medieval origin have survived in their present locations because they are above the highest flood levels experienced in the past millennium has therefore been used in the definition of Flood Risk Category 2 in the fens.

LOWLAND AREAS

9.20 These are extensive areas of relatively flat land which, unlike fenland, have sufficient slope to drain by gravity but are characterised by broad floodplains and wide, slow flowing, often embanked rivers. The River Eau and Barlings Eau catchments are examples of lowland areas. The Trent Valley, upstream of Gainsborough, can also be regarded as a lowland area.

9.21 Many British towns were established close to a river crossing, at a point where the river's natural floodplain was locally narrow and where the width of difficult, marshy ground to be traversed on either side of the river would have been minimised. Such locations would, however, have formed natural "choke points" along the river and although the lateral extent of any flooding would have been limited to the narrow floodplain the depth of flooding would be greater than where the floodplain was considerably wider. Brigg, although just outside of West Lindsey, is a typical example of this phenomenon.

UPLAND AREAS

9.22 The upland areas within West Lindsey are the headwaters of the River Rase and small watercourses in the Wolds.

9.23 The floodplain in these upland valleys follow the course of the streams but are also narrow, rarely extending for much more than 50m on either side of the watercourse. The flood zone envelopes shown on the Environment Agency's Flood Maps, have been studied for anomalies before being transposed onto the strategic flood risk maps (Figure 5.1). At the scale of 1/25,000 generally used for Strategic Flood Risk maps in rural areas, differences between the floodplain defined by the Environment Agency and that defined in this study will generally be of a second order of magnitude.

9.24 The 1 in 1000 year flood envelope in upland areas has been assumed to extend across the whole of the floodplain, but for reasons given in para.5.8, the difference between the 1 in 100 year and 1 in 1000 year flood envelopes in these areas will be fairly small. (This is readily apparent on the Environment Agency's Flood Maps.) In upland areas the 1 in 1000 year (Flood Risk Category 2) envelope is therefore only shown in Figure 5.1 where it extends a visibly significant distance beyond the 1 in 100 year (Flood Risk Category 3a) envelope.

Anthropogenic Influences

9.25 There are a number of large man-made structures in the West Lindsey District which could have a potential impact on flood risk by virtue of the manner in which they may be liable to increase or decrease flood levels for a given rainfall event. Each of these anthropogenic influences is discussed separately below.

FOSSDYKE CANAL

9.26 The Fossdyke Canal runs in a south easterly direction from Torksey Lock to the Brayford Pool in Lincoln. The western part of the canal, as far as Saxilby, is artificial. East of Saxilby, the canal was formed by the canalisation of the River Till and this eastern section of the canal conveys flows from the River Till to the River Witham at Lincoln. Although of Roman origin, the Fossdyke canal seen today dates from the 18th Century.

9.27 The whole of the canal is navigable. The navigation is operated and managed by British Waterways. Sluices at Stamp End and Bargate retain the water levels in Lincoln and along the Fossdyke Canal (Ref 12).

9.28 The Fossdyke Canal itself is only a minor source of flood risk in West Lindsey and there have been no recent recorded flooding events due to the overtopping of the Canal. However, because the Canal originates at the River Trent, if the lock gates fail at Torksey, there is the potential for flood water to move down the Canal increasing the risk of flooding along the canal and in Lincoln. The Tidal Trent Strategy Study (Ref 11) states that if a breach occurred on the River Trent near Torksey, the breach flood cell would extend to the A46 at Skellingthorpe. As there is a channel at 3m OD that runs under the A46, through which flood water could readily flow, many areas in the north west of Lincoln could be inundated if flood waters were to reach a level of 6-7mOD in the breach flood cell.

LOCKS, WEIRS & SLUICES IN WEST LINDSEY DISTRICT

River Trent

9.29 Torksey Lock forms part of the flood defences along the River Trent. The Lock has two sets of mitre gates at each end to enable it to operate when water levels in the Trent are higher or lower than those in the canal. The pair of lock gates west of the A156 road were originally used as flood gates but these have recently been supplemented by an additional pair of flood gates. The outer gates on the west side of the road are the most recent.

9.30 The height of the two pairs of flood gates on the western (River Trent) side of the Lock are 8m and 7.6mOD respectively giving rise to a standard of protection for a 1 in 100 year flood return period event. During an event, the flood defence gates are closed when the level in the River Trent reaches 4.6mAOD.

9.31 The flood levels and therefore the flood risk along the Fossdyke east of Torksey Lock can be heavily influenced by the timing of the flood gates being closed.

River Ancholme

9.32 Below Harlam Hill the flow from the River Rase joins the River Ancholme by flowing over a weir downstream of Harlam Hill Lock. There is another weir upstream of the lock that acts to bypass any excess flow from the Ancholme to the Rase.

9.33 The operation of Harlam Hill Lock is not critical in determining the flood risk in the area as any excess water in the River Ancholme can discharge into the parallel lower level channel of the Rase to the east of the Ancholme.

Caistor Canal

9.34 Along the canal there is a set of six disused locks that have now been demolished. Although the canal now conveys flow of the South Kelsey Beck, these locks have no impact on flood risk.

Hydraulic Models

9.35 One-dimensional hydraulic models of the major rivers in West Lindsey were provided by the Environment Agency and various consultants. None of the models were re-run but the original results were used to create the flood zones in West Lindsey in the vicinity of the modelled rivers. The models obtained and the results used are explained below.

The River Trent Model

9.36 In 2002 the consulting engineers, Black & Veatch, were engaged by the Environment Agency to undertake the construction of a large catchment-scale computer model of the River Trent from Wilthorpe Bridge (SK 805 567) to Trent Falls at the confluence with the River Ouse (SE 866 234) for the Tidal Trent Strategy Study. This model is based on an original National Rivers Authority model and combines fluvial inflows from the Fluvial Trent Strategy, Hydrology Report (2003), tidal levels from Posford Report, with hydraulic modelling of the river channel based on HR Wallingford's ISIS modelling techniques.

9.37 The ISIS procedure is currently regarded as a 'state of the art' technique and has been thoroughly tested in a wide range of applications, separately and in combination, and has found to be accurate and reliable. The ISIS model results may therefore be accepted with confidence.

9.38 The hydraulic component of the River Trent Model incorporates cross sections of the river and associated flood storage reservoirs and natural floodplains as well modelling breaches of the flood embankments at various locations along the river. The breach scenarios are all based on the assumption that the breach will occur after 80 hours. This is assumed to be the time when the level in the River is at its highest.

9.39 Black & Veatch provided flood extents for the 75, 100, 200, 1000 year return period flood events based on the ISIS model results. The 200 year flood return period event results were used to determine Flood Risk Category 3, as the river is influenced by the tide, and the 1000 year results to determine Flood Risk Category 2.

The Upper Witham Model

9.40 In 2006 AECOM were engaged by the Environment Agency to update the large-scale computer model of the Upper River Witham from Claypole (SK 843 489) to Stamp End Lock on the River Witham (SK 498 371). The model also includes the Fossdyke Canal up to SK 486 377, the River Till along all of its length and all other major watercourses within the Upper Witham catchment.

9.41 The model combines distributed hydrological inputs based on the Centre for Hydrology & Ecology Flood Estimation Handbook (FEH) procedures with hydraulic modelling of the river channel and its principal tributaries based on HR Wallingford's INFO Works modelling techniques.

9.42 The FEH and INFO Works procedures are both currently regarded as 'state of the art' techniques. Both have now been thoroughly tested in a wide range of applications, separately and in combination, and found to be accurate and reliable. The model results may therefore be accepted with confidence.

9.43 The hydraulic component of the Upper River Witham Model incorporates cross-sections of the river and associated watercourses obtained from a topographical survey undertaken in 2004. The floodplain is modelled as storage areas or extended cross-sections where there are no embankments present.

9.44 Flood envelopes for the 100 year and 1000 year return periods flood were provided based on the model results and used to determine Flood Risk Categories 3 and 2 respectively.

The Lower Witham Model

9.45 The Lower Witham model extends from approximately 300m downstream of Stamp End Sluices in Lincoln to Boston Dock incorporating the Barlings Eau and the watercourses to the south of the River Witham. The Lower Witham Flood Alleviation Scheme is also included in the model.

9.46 The model combines distributed hydrological inputs based on the Centre for Hydrology & Ecology Flood Estimation Handbook (FEH) procedures with hydraulic modelling of the river channel and its principal tributaries based on HR Wallingford's ISIS modelling techniques. The model results can therefore be accepted with confidence.

9.47 The hydraulic component of the Lower Witham Model incorporates cross-sections of the river and associated watercourses and floodplains of the rivers as well as numerous breaches of the earth embankments. All of the breaches are modelled as the ISIS node unit 'SLUICE'. The breach is based on the head of the water in the channel which then determines the position of the sluice and hence whether a breach occurs.

9.48 The model has only been run for up to the 100 year flood return period event. The 100 year results were mapped using a GIS package and compared with the Environment Agency's Flood Map.

The River Ancholme Model

9.49 Royal Haskoning were engaged with the Environment Agency in 2004 to produce a Project Appraisal for the Ancholme Valley (Ref 17). This included modelling of the River Ancholme from the gauging stations at Bishopbridge (TF 503 391) to the tidal outfall sluices at South Ferriby.

9.50 The model combines distributed hydrological inputs based on the Centre for Hydrology & Ecology Flood Estimation Handbook (FEH) procedures with hydraulic modelling of the river channel and its principal tributaries based on HR Wallingford's ISIS modelling techniques. The model results may therefore be accepted with confidence.

9.51 The hydraulic component of the River Ancholme Model incorporates cross-sections of the river from a topographical survey undertaken in 1996 and a more detailed survey in 2000. The floodplain is modelled as spill units connected to reservoir units and is based on the assumption that only one of the two sluice gates at South Ferriby is open. No IDB pumping stations have been included in the model, and the inflows from various tributaries into the Ancholme have been modelled as flow-time boundaries.

9.52 The model was deemed too inaccurate to be used to produce the flood zones from the model results. Instead, the Environment Agency's Flood Map was reviewed and amended accordingly.

The River Rase Model

9.53 The River Rase model was originally constructed in the mid-1990's using the SALMON-F modelling software to test a range of different flood alleviation schemes for the Rasens. At the time of the model build it was not possible in SALMON-F to accurately represent the proposed FSR and control structures, and therefore the scheme was modelled by calculating the flow out of the FSRs outside of SALMON-F and feeding this in as an inflow.

9.54 By the time the final design was being undertaken, the ISIS software was available. An initial 'course' conversion to ISIS allowed the construction of a shortened model to enable the final design of the FSR control structures. This shortened model extended from the eastern end of the flood storage reservoir on the River Rase to 130m downstream of Jameson Bridge in Market Rasen.

9.55 The model was deemed too inaccurate to be used to produce the flood zones from the model results. Instead, the Environment Agency's Flood Map was reviewed and amended accordingly.

9.56 A one-dimensional hydraulic model of the River Rase and the River Ancholme is currently being approved by the Environment Agency. Once the full results of this modelling are available they should be incorporated into this SFRA. This will aid in advising West Lindsey DC on proposed land allocations.

Actual Flood Risk Mapping

9.57 The strategic flood risk mapping of actual flood risk for West Lindsey and the preparation of the set of ten flood risk maps (Figure 9.1) has been based principally upon the model results of some of the main watercourses in West Lindsey, namely the River Trent, River Witham, Fossdyke Canal, River Till, and the Barlings Eau. The models have provided 100 year, 200 year and 1000 year flood levels for areas of the District surrounding these watercourses thereby enabling the corresponding flood envelopes to be drawn along those watercourses.

9.58 The LIDAR data supplied by the Environment Agency was plotted at 500mm contour intervals with SAR data underneath to provide a complete coverage of the principal floodplains in the District. Flood levels at numerous key locations obtained from the various models were then transposed onto the LIDAR to produce the flood envelopes corresponding to those locations, i.e. the points where the flood level intersected the rising ground. The key locations were selected to ensure that as far as possible changes in flood level between adjacent locations did not exceed 0.2m.

9.59 In transcribing the flood levels derived from the Lower Witham Model to their specific locations on the working plans of the River Witham, the Flood Risk Category 3 created from the model results was larger than the Environment Agency's Flood Zone 2. It was decided that the model results for the River Witham should not be used but the Environment Agency's flood map should be amended, informed by the model results.

9.60 All of the models used to produce the strategic flood risk maps have included the effects of any flood alleviation schemes on the rivers modelled. The attenuating effects on flood flows created by the River Till Washlands are allowed for in the Upper Witham model in which the Washlands are specifically incorporated. Therefore the N-year flood flows and corresponding flood levels generated by the model along the River Till and Fossdyke Canal automatically include the effects of the Washlands.

9.61 Where there were no models the Environment Agency's Flood Maps were studied in detail. Anomalies similar to those described in Section 3 were identified and the flood envelope revised accordingly. The flood risk assessment is made on the assumption that the full width of the floodplain will be affected by all floods in excess of the 100 year return period. In reality, the difference in width between the 100 year and 1000 year flood envelopes on these narrow floodplains is too small to be represented on strategic-scale maps.

9.62 It should also be noted that there are many IDB drains within West Lindsey which only generally provide up to a 1 in 10 year standard of protection against flooding. A site-specific flood risk assessment would need to consider the risk of flooding to a new development from an IDB watercourse for a 1 in 100 year with the inclusion of climate change event.

9.63 During a flood the water level in a river will rise above the ground level in areas defended by flood banks or flood walls. 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 outfall.

9.64 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.

9.65 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, although 'tidelock' conditions in urban areas draining to tidal waters cannot be disregarded.

9.66 The effects of floodlock (or tidelock) can be overcome by the installation of land drainage pumps behind the defence line so that the flows in the floodlocked sewers or tributaries 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.

9.67 The risk of fluvial floodlocking occurring within West Lindsey is small. Floodlocking would only occur as a local problem. Low lying areas adjacent to the River Trent experience tidal floodlocking ('tidelock'). When the tide comes in the level in the river rises causing floodlocking. The duration of the flood locking is no longer than two hours and due to the standard of defences along the River Trent the impact is small. Floodlocking will however increase in both tidal and fluvial scenarios with increasing climate change.

Flood Risk Mapping – Climate Change Scenario

9.68 There was no data available showing the flood outline for the 'with climate change' scenario in accordance with PPS25 for any of the major rivers previously modelled within West Lindsey. After discussions with West Lindsey DC it was decided that the climate change modelling scenario should be undertaken along the River Trent due to the District's main town, Gainsborough, being situated adjacent to the river.

9.69 Black and Veatch Ltd had originally developed an ISIS hydraulic model of the tidal section of the River Trent as part of the Tidal Trent Strategy Study and were therefore commissioned by AECOM to undertake the 'with climate change' modelling in accordance with PPS25.

9.70 Black and Veatch used unmodified versions of the ISIS model used for the Trent Strategy Study and updated the hydrology in accordance with PPS25 to model the impact of climate change up to the year 2115 on both flood flows and peak tide levels. Climate change scenarios were modelled for the 25, 200 and 1000 year return period flood events.

9.71 The results from the modelling were mapped by Black and Veatch and the resulting flood outlines were provided to AECOM. These flood outlines are shown in Figure 9.2. The results show that the flood extents for all of the modelled return periods to be very similar; being confined to the lower lying areas of land (the edge of the floodplain). Appendix A contains the full report provided by Black and Veatch documenting the methodology used for the 'with climate change' scenario modelling.

Flood Hazard Mapping

9.72 In addition to the Strategic Flood Risk Maps the Brief required the production of maps showing the maximum velocities, depths of flooding and extent of flooding as a result of the breaching of raised flood defences.

9.73 In a major flood event where a river is confined within raised 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 flood wall 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 a person 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 serious consideration in flood risk assessment.

9.74 The Gainsborough and Bardney study areas are where WLDC are proposing key future development and these locations were therefore chosen for the breach analysis. The outputs of flood depths and velocities from the 2D modelling will enable WLDC to apply the sequential test in those areas.

9.75 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 (Ref 18).

9.76 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

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

9.78 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.

9.79 The flood defence breach models were developed using the two-dimensional modelling software Tuflow. Tuflow is a computer program for simulating depth-averaged, two and one-dimensional free-surface flows such as occur from floods and tides. Tuflow, originally developed for just two-dimensional (2D) flows, stands for Two-dimensional Unsteady Flow. It incorporates the full functionality of the ESTRY one-dimensional (1D) network or quasi-2D modelling system based on full 1D free-surface flow equations.

9.80 A powerful feature of Tuflow is its ability to link the 1D network domain to 2D domains dynamically to form a single model. An ISIS-Tuflow link was developed by Halcrow and is utilised in the breach scenario used at Bardney. The 2D component of the model was built using the Tuflow Build 2007-07-AF hydrodynamic modelling software.

Impact of Climate Change

9.81 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. Climate change is unlikely to have any significant impact on the velocity, depth or extent of the hazard zone.

Gainsborough

9.82 Three separate breach locations were modelled in Gainsborough. The three locations were chosen based on a weak or lower spot in the defences. The locations were:

1 The earth embankment defence at the allotment gardens to the south of North Warren Road (SK 480 390).

2 The concrete flood wall at the supermarket car park near the Ropery Road / Caskgate Street junction (SK 481 389).

3 The earth embankment with open grassland on the landward side to the south of River Trent railway bridge (SK 481 388).

9.83 A breach was simulated through the defences at each of the above locations during a 1 in 200 year event in the Trent. The Tuflow methodology used for the Gainsborough breach scenarios is outlined in detail in Appendix B.

9.84 For each of the breach modelling scenarios maximum flood depths and velocities as a result of the breach have been mapped as Figures 9.3.1, and 9.3.2 respectively. To produce the flood hazard rating, Figure 9.3.3, these results have been used and interpolated for those areas outside of the modelled breaches to give an overall impression of flood hazard for Gainsborough. For the flood the corresponding flood extent is shown on Figure 9.1. The model results show that the majority of Gainsborough in the immediate vicinity of the River Trent experiences depths of flood water above 2mOD and velocities about 1m/s. However, it should be noted that the velocities, in particular, are very dependent on the location of the breach in the defences. A different pattern of depths and velocities would prevail even if the breach was 10m upstream or downstream of the chosen location.

Bardney

9.85 Only one breach location was modelled at Bardney. A 1D ISIS hydrodynamic model of the River Witham was linked with a 2D model of the river's left bank floodplain at Bardney to model the impact on the old sugar factory site of a breach in the earth embankment defences. The breach location was chosen slightly downstream of the factory at a low spot in the defences. The modelling investigated the 1 in 100 year event in the River Witham as 'with climate change' flood levels were not available at the time of undertaking the study. A full explanation of the modelling methodology and assumptions made is also described in Appendix B.

9.86 The Bardney breach modelling results show that the majority of the sugar factory site becomes inundated with flood water. However Bardney village remained unaffected as it is situated on slightly higher ground. Maximum flood depths were about 2.7mOD adjacent to the defences and 0.2mOD 200m east of the defences. The velocities experienced as a result of the breach were minimal. At the onset of the breach the velocity reached 0.6m/s at the landward side of the embankment with velocities to the south of the breach greater than those to the north due to the direction of the flow being mainly southwards.

9.87 The maximum flood depths and velocities and flood hazard rating as a result of the breach have been mapped as Figures 9.3.4, 9.3.5 and 9.3.6 respectively. It must noted that these results are only based on one breach location and the flood hazard will vary across the site should a breach occur in different locations. A more detailed breach analysis will be required for any potential development proposals to this site, and elsewhere in Bardney. The corresponding flood extent is shown in Figure 9.1.

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Assessment of Flood Risk in the Study Areas

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10 Assessment of Flood Risk in the Study Areas

10.1 Any useful assessment of flood risk within the four study areas identified by the District Council (Table 1.1) as being possible locations for potential development requires an evaluation of actual flood risk over the whole of the study area. This will enable the Council to apply the sequential test required by PPS 25, both as regards the variation of flood risk within a study area and also for the purposes of ranking study areas in accordance with their respective overall degree of flood risk.

10.2 As the PPS 25 flood zones are based on the situation that would be obtained in the absence of any flood defences, it follows that within any PPS 25 flood zones the actual level of flood risk will depend on the existence of flood defences and the standard of protection provided by those defences. Assuming that its envelope has been correctly drawn, within any PPS 25 Zone 3a (High Probability) there may be areas which are protected to a higher standard than 1% (1 in 100 years). In these cases their actual flood risk classification will be Category 2 (Medium Probability). In practice, this will only apply to Zone 3a since flood protection to a higher standard than 0.1% (1 in 1000 years) is unheard of.

10.3 The degree of actual flood risk throughout each of the four study areas, expressed in terms of actual 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 hundred years are considered to be sufficient to transfer a study area to a higher Category this will be stated in the assessment.

10.4 Flood risk sources considered in the 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.

10.5 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. It is, however, assumed that no development would be permitted that would so restrict the capacity of any watercourse that flooding would be caused or exacerbated upstream of the development.

10.6 The four individual flood risk assessments will be presented in a common format, under the following headings:

a) General description of the study area

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

c) Flood risks within the study area

d) Flood risks to downstream areas

10.7 Assessment of flood risk in the study areas must also consider the particular case of the potential hazard to life and limb from fast flowing flood water that could occur in close proximity to a sudden breach in a flood defence. This could occur within a defended area in the event of the collapse of a flood wall or embankment. As the depth and/or velocity of an inrush of flood water increases, there comes a point where an adult is no longer capable of standing upright in the flow and could be swept away and drowned.

10.8 The area immediately behind the flood defence line within which a serious risk to life and limb could occur is known as the Rapid Inundation Zone or Hazard Zone. This has already been discussed in some detail in Section 9 with modelled depths and velocities ascertained from 2D breach modelling in the defences at Gainsborough and Bardney.

10.9 The flood risk assessments of the study areas made in Section 11 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. Appendix C outlines a skeleton contents page detailing what should be included in a site-specific flood risk assessment.

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Study Areas in West Lindsey

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11 Study Areas in West Lindsey

11.1 The location of the four urban study areas in Gainsborough, Market Rasen, Saxilby and Bardney for which flood risk assessments are required have been listed in Table 1.1 and are shown in Figures 1.2.1, 1.2.2, 1.2.3 and 1.2.4.

11.2 The study areas incorporate the whole of the urban area and its fringes within each of the four towns or villages, ranging in size from 1 to 11km^2.

11.3 Of the four study areas, all are partly within Flood Zone 3 as shown on the Environment Agency's Flood Zone Maps. The main areas that fall within this flood zone in each of the study areas are outlined below:

Gainsborough	the western edge of the study area as far east as the A159 and A156 major roads.
Market Rasen	the River Rase's natural floodplain through the town.
Saxilby	the southern edge of the study area.
Bardney	the north of the study area along the B1202 road adjacent to Field Lane, and north of Carron Close along Abbey Road. Parts of the sugar factory site in the south west of the study area and the pumping station to the north west of the study area.

11.4 A more detailed description of the areas that fall into the Flood Zone 3 is described for each of the study areas later in this section.

11.5 All of the study areas lie within the floodplain of a Main River; Gainsborough the River Trent; Market Rasen the River Rase; Bardney the River Witham; and Saxilby the Fossdyke Canal. The hydraulic model results for these rivers, with the exception of the River Rase, have been used to make a detailed evaluation of the flood risk in the corresponding study area.

11.6 The floodplains of the smaller watercourses in the West Lindsey study areas, namely the Brimmer Beck, and drains in Bardney and Gainsborough have not been considered at a strategic level. As their floodplains are very narrow, any flood risk associated with these watercourses would be localised.

11.7 Urban development within a floodplain raises the question of "displaced water" and the potential loss of natural flood storage volume within the floodplain. 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". However, displaced water should not necessarily be a significant issue in the study areas if the development takes the form of redevelopment of 'brownfield' land where the proposed buildings have a 'footprint' comparable to that of existing or previous buildings on the development site. Opportunities for providing betterment should always be considered and implemented where possible.

11.8 Some of the surface water sewers in the study areas are of considerable size at their downstream ends when they outfall into open watercourses and thus constitute potential flood risks over a significant area. These larger surface water sewers have been taken into account in the study area flood risk assessments and, where appropriate, are shown on the study area plans. Plans showing the principal hydrological and hydraulic features in each study area are presented as Figures 11.1 to 11.4. These plans should be read in conjunction with the appropriate Strategic Flood Risk map.

GAINSBOROUGH

General Description of the Study Area

11.9 Gainsborough, the largest town within West Lindsey, is situated on the right bank of the River Trent approximately 45 kilometres from the Humber Estuary. The town has developed along the river at the foot of a scarp slope. In the core of the town there is vacant, previously developed, land due to the loss of industry in the area. The majority of the study area consists of urban development whereas in the south of the area more open spaces and woodland prevails.

11.10 Included in this study area is the suburb of Morton to the north of Gainsborough, and the village of Lea to the south.

11.11 Morton extends north west from Front Street in Gainsborough along Walkerith Road until Laughton Road. Recently, development has taken place to the north of Morton Warping Drain.

11.12 Lea, 2.5km south of Gainsborough, is a small village situated between the A156 to the west and the railway line to the east. The village is located on a stretch of higher ground in comparison to the land adjacent to the River Trent. The area of land between Lea and the River Trent, Lea Marshes, is a large area of floodplain that is able to flood during inundation events.

11.13 The study area is 11.69 km^2 and its extent is shown in Figure 1.2.1.

Hydrology of the Study Area

11.14 The River Trent is the only major river in the vicinity of the study area and forms its western boundary through Morton and Gainsborough. Lea is situated about 200m east from the right bank of the River. The Environment Agency's Flood Map shows that the floodplain of the River Trent extends to the A159 and covers the whole of Lea Marshes.

11.15 Humble Carr Drain to the south of the study area flows in a predominately north westerly direction from Gainsborough sewage treatment works to the River Trent. Once the flow in the Drain has reached the River Trent it is pumped into the River at the Pauls Maltings Pumping Station.

11.16 Morton Warping Drain, in the north of the study area, flows in a north easterly direction from the River Trent through the centre of Morton. Morton Poor Drain joins Morton Warping Drain at the northern extent of the study area and flows north easterly into the Gainsborough IDB's arterial drainage system.

11.17 To the east of Gainsborough, Heapham Road balancing ponds on Somerby Drain act to store urban runoff and alleviate flooding. The balancing ponds cover an area of 1.8ha, and provide a storage volume of 28600m^3 (equivalent a 1 in 50 year event).

11.18 A small drain flows in a south easterly direction along the eastern side of the factories on Heapham Road and another small ditch drains the housing estate to the north of Foxby Lane. There are several small ditches to the south of Foxby Lane. Some of these ditches are very overgrown.

11.19 Severn Trent Water's 1/1,250 scale sewer plans of Gainsborough show numerous surface water sewers within the study area ranging from 150mm in diameter to 970mm in diameter. For the purposes of this strategic flood risk assessment, only sewers with a diameter of 500mm or greater are considered to have a significant impact on flood risk within the study area.

11.20 The locations of these sewers are shown in Figure 7.1. The larger surface water sewers are located in isolated areas in the east of Gainsborough. A combined (foul and surface water) sewer system is located in the west of the study area. These sewers stretch from North Warren Road south towards Gainsborough Lea Road railway station ranging in diameter from 525mm to 1500mm.

Flood Risk within the Study Area

11.21 The western strip of the study area from the right bank of the River Trent towards the A159/A156 is located in Flood Risk Category 3. The only exception is an area of land to the north of the sewerage works at Lea that is located in Category 1. The rest of the study area to the east of the A159/A156 is mainly Category 1.

11.22 The main risk of flooding in the study area is from the overtopping or breaching of the earth embankments or flood walls along the eastern bank of the River Trent. The flood defences north of the sewage works at Lea have a standard of protection of 1 in 100 to 1 in 200 years. The 200 year design water level in the Trent is on average 6.5mOD, below the crest of the defences; therefore overtopping/breaching should only occur during an event with higher water level than the 1 in 200 year event. It is possible that breaching of an earth embankment or a flood wall could occur during an event lower than the 1 in 200 year. This may be due to the disrepair or deterioration of the structure. Maintenance of the defences is therefore essential to minimise flood risk. The failure of the defences as a result of a breach in Gainsborough has been investigated in Section 9 of this Report where details of the breach scenario locations and modelled results will be found.

11.23 South of the sewage works the standard of protection of the earth embankments is for a 1 in 2 year event. The agricultural land adjacent to the river is intended to be inundated with water during flood events. This alleviates the volume and therefore the water level in the river downstream at Gainsborough. The Beckingham Marshes to the west of Gainsborough also act to store water to alleviate flooding in Gainsborough.

11.24 Gainsborough last experienced major flooding from the River Trent in 1947 in which at breach developed at Morton Corner – see Section 4. This event occurred before the construction of the latest flood alleviation scheme.

11.25 The only land drainage pumping station in the vicinity of the study area is Pauls Maltings Pumping Station to the south of Gainsborough. The station is situated at the end of the culverted Humble Carr Drain and consists of one pump. Gainsborough IDB stated that the pump has never failed. However the IDB stated that if the pump were to fail, Gainsborough would not be affected. There would be the potential for properties along Lea Road to experience flooding though it was noted by the Board that the low lying land adjacent to the drain would probably alleviate any flooding to the properties themselves.

11.26 There is a minimal flood risk from Morton Warping Drain in the north of the study area. The first 200m of the watercourse has been culverted, and at present, the culvert is in a state of disrepair. Despite the condition of the culvert, during the heavy rainfall experienced in June 2007, the drain did not experience any flooding.

11.27 The small ditches in the south of the study area have a minor and localised flood risk. This should be considered as a residual risk, and its impact would probably be confined to local waterlogging.

11.28 The surface water sewerage system in Gainsborough would cause a localised flood risk if the system became blocked or overloaded during intense rainfall. The Environment Agency has noted that Gainsborough has experienced many surface water events causing localised flooding. In August 2004, many areas of Gainsborough experienced flooding due to the inadequacy of the sewerage system, in particular Church Street and Tower Street.

11.29 The adequacy of the surface water sewers in Gainsborough is discussed in more detail in Section 8.

Flood Risk to Downstream Areas

11.30 All surface water runoff from the Gainsborough study area discharges directly or indirectly by pumping to the tidal River Trent. The catchment area of the river upstream of Gainsborough exceeds 8300 sq.km and the relative contribution of runoff from Gainsborough to flood flows in the river will be minimal. The impact of Gainsborough runoff on flood risk downstream can therefore be ignored.

MARKET RASEN

General Description of the Study Area

11.31 Market Rasen is the second largest town in the District and lies on the edge of the Lincolnshire Wolds Area of Outstanding Natural Beauty. The 4.5 km^2 study area extends north towards the Brimmer Beck, eastwards incorporating the racecourse and westwards to the western edge of Middle Rasen.

11.32 The main part of the study area includes the town of Market Rasen. The east of the study area incorporates farmland to the right of B1203 and the River Rase North Branch Reservoir. In the south east corner of the study site, north of Legsby Road, the land is slightly higher and forms the racecourse. Just outside the eastern extend of the study area lies Willingham Woods. The western square of the study area includes the village of Middle Rasen lying in a valley with higher land to the north and south of the village, see Figure 11.2.

Hydrology of the Study Area

11.33 The River Rase (an Environment Agency Main River), originating in the Wolds, flows west through the centre of the study area. The floodplain of the river forms a narrow strip extending, on average, 40m from the river throughout the study area. At Jameson Bridge in the centre of the town, the river splits into two branches; the River Rase and the River Rase South Branch. The FEH catchment area of the River Rase and South Branch upstream of Jameson Bridge is 31.48km^2.

11.34 The Brimmer Beck flows south westerly along the northern boundary of the study area at Market Rasen, entering the study area to the east of Low Church Road in Middle Rasen. The Brimmer Beck joins the River Rase to the south of North Street. The Beck is not a Main River. The FEH catchment area of the Beck is 10.58km^2 at its confluence with the River Rase.

11.35 An open drain originates to the north of Market Rasen primary school and flows south alongside the B1202 road and joins the River Rase at the community centre. A 375mm diameter surface water sewer that flows westerly from Jameson Bridge Street discharges into the drain at its upstream extent.

11.36 Another small open drain to the west of Chapman Street (south of Willingham Road) discharges water into a 750 mm diameter surface water sewer at Chapman Street. This sewer runs west to Dear Street where it turns north and discharges into the River Rase.

11.37 Anglian Water's 1/1,250 scale sewer plans show in south east of Market Rasen, two private sewers discharging into a pond to the north of 'The Ridings' housing estate, one into the north and one into the south of the pond. Two other private sewers also discharge into an open drain that flows northwards from Legsby Road towards DeAston School.

11.38 In Market Rasen the sewer plans show three surface water sewers discharging into the River Rase. One 375mm pipe flows south from the eastern side of the industrial estate to the south of Gallamore Lane and one 450mm flows south from the western edge of the same industrial estate discharges into the Rase right bank. The other 500mm diameter pipe discharges into the Rase left bank at King Street. Photographs of these outfalls are included at the end of the report.

11.39 In Middle Rasen seven more surface water sewer pipes discharge into the River Rase. A 225mm diameter pipe enters the left bank of the River Rase from 'Dovecote' housing estate and a 150mm diameter pipe discharges into the right bank opposite this. Further downstream a 300mm pipe discharges in the left bank of the River from Church Street and a 225mm pipe from Naylors Drive. A 150mm also enters the left bank north of Wilkinsons Drive. At the junction of Stockmoor Lane and Marsh Lane, a 300mm pipe discharges into the right bank of the river and a 225mm pipe into the left bank. However during the site visit, there was no visible evidence of these last two outfalls.

11.40 All the surface water sewers in the study area greater than 500mm in diameter are shown in Figure 11.2. The main surface water sewers are located in the centre of Market Rasen and along the main roads in Middle Rasen.

11.41 The study area also has a combined sewer network as shown in Figure 11.2. These flow along the principal roads within the study area, for example Willingham Road, Jameson Bridge Street, Chapel Street, and Gainsborough Road as far as Marsh Lane. These sewer pipes range in size from 225mm to 450mm.

Flood Risk within the Study Area

11.42 The land adjacent to the River Rase and its South Branch in Market Rasen are located in Flood Risk Category 3. The area of open land north east of Crane Bridge lies within Category 2. In Middle Rasen, west of Low Church Road, the open fields are located in Category 3 as well as the open land to the east of Marsh Lane. Only properties within the narrow corridor along the River Rase are located in Category 3. The rest of the study area is located in Category 1.

11.43 The greatest flood risk in the study area is from the River Rase. There are no raised defences along the river banks; the channel is mainly natural throughout the study area. Overtopping of the banks can therefore create a significant flood risk. Following flooding in 1993, due to heavy rainfall, two Flood Storage Reservoirs were built to alleviate flooding in Market Rasen by controlling the levels in the river. The standard of flood protection has thus been increased from a 1 in 10 year event to a 1 in 75 year event. The Flood Storage Reservoirs are classified as Flood Zone 3b – Functional Floodplain. Flooding of the North Reservoir occurred in 2000, and the South Branch reservoir flooded in 2002, however there are no records that the Market Rasen was affected in either event.

11.44 At the end of this report there are photographs of the outfalls and the North Reservoir. Access could not be gained to the South Reservoir.

11.45 Overtopping of the Brimmer Beck is a minor flood risk. The land affected from overtopping would be agricultural land to the north of Market Rasen and in Middle Rasen, with the flood risk to property small.

11.46 The surface water and combined sewerage systems would cause a localised flood risk if the systems became overloaded or blocked during intense rainfall.

Flood Risk to Downstream Areas

11.47 The majority of the study area is already urbanised. Any further development is not likely to create any large increase in the volume of runoff discharged to the River Rase. Downstream of Middle Rasen the Rase flows through an essentially rural area. However, below Bishopbridge the river flows in an embanked channel where the impact of flooding through a breached floodbank could be extensive. For this reason runoff from any substantial development in the study area should be attenuated to existing rates and volume.

SAXILBY

General Description of the Study Area

11.48 Saxilby is a village situated 7.5km north west of the City of Lincoln. The northern boundary of the study area is Church Lane and its eastern boundary is the B1241 road beyond which lies agricultural land. The railway line from Gainsborough to Lincoln forms the western boundary and the Fossdyke Canal the southern.

11.49 The 2.11km^2 study area's principal component is the village of Saxilby and Saxilby Enterprise Park. The only large open space within the study area is between Church Lane and Westcroft Drive in the north of the study area which is used to graze livestock.

11.50 The topography of the study area shows the land rises in a north easterly direction from the Fossdyke Canal to elevations of 15mOD in the north east of the area.

Hydrology of the Study Area

11.51 The Fossdyke Canal is the only Main River in the study area. The Canal runs along the southern edge of the village, but to the north of the Enterprise Park. Its floodplain extends into the south of the village as far north as Torksey Avenue and includes the whole of the Enterprise Park. The River Till enters the Fossdyke Canal about 2km downstream of Saxilby

11.52 An open watercourse flows in an easterly direction along the southern boundary of the Enterprise Park to a land drainage pumping station to the south east of the study area.

11.53 Anglian Water's 1/1,250 scale sewer plans of Saxilby show numerous surface water sewer pipes flowing along the majority of the principal roads within the study area towards the surface water pumping station at the junction of Bridge Street and High Street, as shown in Figure 11.3. In the south of the study area a 1050mm surface water sewer pipe begins on Queensway and directs water westwards along Bridge Street to this pumping station.

11.54 Moving north from the pumping station and along High Street there is a 1200mm pipe as far as Highfield Road. North of this road, to Manor Road, the pipe is slightly smaller with a diameter of 900mm. From Manor Road to South Parade the pipe diameter is even smaller at 375mm. Two 1050mm pipes along Kenilworth Road and Warwick Close join a 300mm pipe that connects to High Street. Sykes Lane has two pipes, 300m and 450mm channelling water towards the High Street.

11.55 There is also a private surface water sewer in the south east of the study area from Hotchlan Avenue.

11.56 The study area does not have any combined sewer pipes.

Flood Risk within the Study Area

11.57 Flood Risk Category 3 extends as a 200m wide strip north eastwards from the railway line, starting at Western Avenue towards Queensway. To the east of Queensway the whole of the study area is located in Category 3.

11.58 The main flood risk in the study area is from the Fossdyke Canal as the southern part of the study area lies within its floodplain. The banks of the Canal have a standard of protection for a 1 in 100 year event minimising the flood risk to events larger than this. There are no records of flooding in Saxilby from the Fossdyke Canal.

11.59 If the surface water pumping station in the south of the study area were to fail, it is possible that the water in the system would back up causing localised flooding from excess surface water. No information has been received from Anglian Water on the potential impact on the failure of the station.

11.60 The failure of the flood gates at Torksey poses a residual flood risk to flooding in the study area. Water from the River Trent would be able to flow along the Fossdyke Canal potentially increasing water levels in the vicinity of the study area and hence increasing the flood risk.

Flood Risk to Downstream Areas

11.61 The study area is mostly urbanised at present therefore any further development is not likely to increase the amount of runoff into the Fossdyke Canal or into downstream areas significantly. Runoff from Saxilby discharges to the canal, either directly or indirectly, and is conveyed east along the canal to the River Witham at Lincoln. Although the resultant effect on increased flood risk in Lincoln is likely to be minimal, any runoff from significant development in Saxilby should be attenuated to existing levels.

BARDNEY

General Description of the Study Area

11.62 Bardney is a village situated on the left bank of the River Witham approximately 13.5km downstream of Lincoln. The village has grown outwards from the road junction at the east end of the village.

11.63 The study area includes the whole of the village of Bardney and the old Sugar Factory site located to the south west of the village on the left bank of the River Witham. The majority of the study site consists of existing housing. The only open space in the study area is the fringe of farmland that surrounds the village.

11.64 The topography of the area shows that the land rises from the banks of the River Witham in a north easterly direction toward the centre of the study area. To the east of the village centre the land slopes back down again towards Bardney Common.

Hydrology of the Study Area

11.65 The River Witham is the only Main River in the vicinity of the study area and forms its western boundary. Its floodplain extends as far east as the sewage pumping station north of Bardney Bridge. South of the road bridge the floodplain extends as a narrow strip of land adjacent to the river, encroaching slightly onto the Sugar Factory site.

11.66 There are numerous open watercourses in the study area. Abbey Drain originates from the east side of Carron Close housing estate and flows north westerly around the estate crossing Abbey Road before flowing north out of the study area. Chestnut Drain flows south westwards before turning through 90^{o} to flow south eastwards adjacent to the Sugar Factory site. The drain connects to Engine Drain which flows eastwards and is pumped into the River Witham at Manor Farm pumping station. Chestnut drain is approximately 2 metres deep, 2½ metres wide at the bottom of the channel and 7 metres wide at the top. There are 8 or 9 flow retarders along the full length of the drain.

11.67 There is also a drain extending northwards from the sewage pumping station and two ditches draining Lea Grove housing estate.

11.68 The only surface water sewers in the study area are a system of 150mm and 225mm diameter pipes in Carron Close housing estate. The system outfalls into Abbey Drain.

11.69 There are no combined sewers in the area but there is a system of private sewers between Manor Farm and Chestnut Drain.

Flood Risk within the Study Area

11.70 The north of the study area is situated in Flood Risk Category 3 affecting properties on Wragby Road north of Field Lane and Abbey Road north of Carron Close. The pumping station and the south west of the Sugar Factory site are also located in Category 3.

11.71 The primary flood risk is from the River Witham. The river is embanked on both its east and west banks. The 100 year water level of 4.3mOD, predicted from the Lower Witham Model, shows that the water does not overtop the left bank of the river at Bardney. During a 100 year event, the right bank of the river is overtopped causing the flood risk to the study area to be minimal.

11.72 There is a residual risk of flooding from a breach in the left bank of the River Witham at Bardney. The failure of the left bank defence downstream of the old Bardney Sugar Factory has been investigated in Section 9 of this report where details of the modelling of the breach scenario will be found.

11.73 There is a minimal risk that the study area will be affected by flooding from the low level arterial drainage system, including Chestnut and Abbey Drains. If a blockage occurred in any of these drains then overflow onto the adjacent land could occur.

11.74 Flooding could also occur in the study area as a result of high intensity, short duration, localised storms which produce runoff rates which cannot be taken into drains quickly enough. These types of incidents usually only result in shallow flooding which can normally be contained within the depths of kerbs on roads and in car parking areas.

Flood Risk to Downstream Areas

11.75 The study area is mostly urbanised at present therefore any further development will only increase the amount of runoff into the arterial drainage network and thence to the River Witham by a modest amount. Nevertheless, because any runoff from future urban development in Bardney will have to be pumped into the river it will be necessary to ensure that this runoff is attenuated in rate and volume to existing levels before it is discharged to the arterial drainage system.

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Surface Water Drainage in Gainsborough

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12 Surface Water Drainage in Gainsborough

12.1 As part of the Brief, West Lindsey requested that the adequacy of the surface water regime in Gainsborough was assessed. This assessment has been based on data provided from West Lindsey District Council's records of flooding in Gainsborough. West Lindsey District Council only started keeping a record of flooding incidents in Gainsborough since August 2004 when parts of the town were seriously affected by localised surface water flooding. No information relating to sewer flooding was able to be obtained from Severn Trent Water.

12.2 The main problem area of surface water flooding in Gainsborough is in the 'downtown' area of the town. Figure 12.1 presents the location of the problem areas and the sewers stated below. It has been noted by West Lindsey District Council that there has been a persistent problem at the lower ends of the sewer systems, especially from the sewers in Tower Street, North Street, New Street, and Church Street. A report produced by West Lindsey District Council in August 2006 assessed the surface water flooding in these lower systems. It was concluded that the area most consistently affected by sewer flooding is between 62 and 100 Church Street (between Acland Street and New Street).

12.3 After investigation it was discovered that the surface water from All Saints Church and New Street seem to be significant contributory factors to this localised flooding. Reports and observations indicate that the surface water from the church roof was not being discharged via the sewer system; instead it was cascading out of the gulleys and along Church Street. The natural route of drainage from the Church should be along Church Street but it is evident that the 300mm diameter pipe is not adequate to discharge the runoff during severe rainfall events. Subsequent to the 2004 flooding West Lindsey District Council have noted that an interceptor gulley was put in place by the County Council Highways Department at this location but, from observations by the Council, this is ineffective at alleviating the surface water problem.

12.4 During peak inundation, it has been noted by West Lindsey District Council that the configuration of the combined sewers is such that drainage in New Street is unable to cope and surface water flows overland into Church Street before it can drain away. New Street appears to be the main conduit for a significant area of central 'uphill' Gainsborough. The pipe size of this sewer is unknown but due to the overland water it appears that pipe is not adequate enough to contain all the flow from the uphill area and the surface water runoff in the vicinity of the pipe. Once the flow has passed through New Street, the water then has to compete for access into the Acland Street sewer due to the flow moving south along Church Street from Bayard Street, exacerbating the problem.

12.5 As the sewers in Tower Street and North Street discharge into the New Street sewer during times of peak inundation, these sewers can have a contributory effect to the problems caused in Church Street. Backing up of water can also occur in these sewers causing consequential flooding in the Tower Street area.

12.6 West Lindsey has also reported problems of surface water flooding in the 600-940mm diameter sewer in Lord Street (just south of All Saints Church). It is thought by the Council that this problem is not linked to the problems in Church Street; however this sewer does connect to the sewer system to the west of Acland Street.

12.7 Development in the 'uphill' part of Gainsborough is thought to be the cause of the problem in the lower system. However the Council have noted that the drainage of this area is mainly towards the Causeway Lane sewage treatment works, not North Warren Road. This shows that recent development may not be the cause of the surface water problem but that the sewer system in the area is just not adequate to contain all the surface water during intense rainfall.

12.8 In 2007, the redevelopment of the Marshalls works site was affected by surface water as well as Tower Street again giving rise to the question of the adequacy of the system but further investigation is required.

12.9 The ‘downtown’ area of Gainsborough is not the only area where surface water drainage has been a problem. In the uphill part of the town, in particular the Park Springs area, the private and public sewers have been overloaded with water during storm events. Since 2004 a public surface water sewer and the pumping station have been replaced to help solve the problem. No details are yet available to assess the effect of the new system.

12.10 Before further development occurs, especially in the downtown area of Gainsborough, the surface water sewerage system needs analysing in detail as further urban development could increase the already significant local flooding problems.

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Sequential Approach

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13 Sequential Approach

13.1 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.

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

13.3 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.

13.4 A level 1 SFRA will enabled WLDC to use the sequential approach by applying the sequential test to future land allocations.

13.5 The sequential test undertaken for their current growth aspirations has indicated the possibility of further development in areas of flood Zone 3 and 2 in Gainsborough and Bardney.

13.6 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 DPD 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 FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

13.7 In order to inform the exception test to identify if development is required in these areas, for other sustainable development reasons, a more detailed level 2 SFRA has been identified. This detailed SFRA has defined the actual flood risk within the flood zones and, if development is identified, this will also enable the sequential approach to be applied to those areas.

Gainsborough

13.8 Significant parts of the study area are shown to be in Flood Zone 1, with little or no flood risk, and these should be developed in preference to other, higher flood risk areas.

13.9 However, in the older part of the town some brownfield redevelopment can be expected in areas of Flood Zone 3 and 2. In these areas, whilst the actual flood risk due to the presence of the defences could be considered as acceptable, there is a significant danger from a breach.

13.10 The hazard map shows that an area of "Danger for All" exists and development in this area should not be allowed to take place.

13.11 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 DPD 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 FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

13.12 In areas of “Danger to Most” the exception test will need to show that further development is required for wider sustainable development reasons. Where this is the case careful consideration of the risk will need to be undertaken by any applicant through their site specific Flood Risk Assessment and detailed mitigation measure implemented.

Bardney

13.13 The existing residential part of the study area is within in Flood Zone 1, with little or no flood risk, and this should be developed in preference to other, higher flood risk areas.

13.14 However, redevelopment of the existing sugar beet factory will be in areas of Flood Zone 3 and 2. In this area, whilst the actual flood risk due to the presence of the defences could be considered as acceptable, there is a significant danger from a breach.

13.15 The hazard map shows that a small area of “Danger for All” exists on the site and development in this area should not be allowed to take place.

13.16 The majority of the site is in an area of “Danger to Most” and the exception test will need to be passed, as identified in paragraph 13.11 above, and will need to show that further development is required for wider sustainable development reasons. Where this is the case careful consideration of the risk will need to be undertaken by any applicant through their site specific Flood Risk Assessment and detailed mitigation measure implemented.

Improvement Work Costs

14 Improvement Work Costs

14.1 As part of the Brief, West Lindsey District Council required the identification of the extent, budget estimate of costs and practical constraints of any works required to raise the existing flood defence standard to 1 in 100 years for fluvial rivers and 1 in 200 years for tidal rivers throughout the District.

14.2 The investigation was limited to the Main Rivers in West Lindsey, namely the River Trent, the Fossdyke Canal, River Till, River Witham, Barlings Eau, River Ancholme, and to the River Rase Flood Storage Reservoirs.

14.3 The Environment Agency's Tidal Trent Strategy Study (Ref 11) was used to obtain the existing standard of protection of the defences along the River Trent and the Environment Agency's NFCDD for the remaining rivers.

14.4 In order to calculate the cost required to raise the standard of defences that were identified as being below the required standard of protection the following assumptions were made:

- The level of freeboard required is 600mm.
- The width of the crest of earth embankments is 4m.

14.5 The criteria used to derive the estimated costs of flood defence improvement works are outlined in Table 14.1 below:

Unit Costs (2007)	
Clay import and fill	£15/m^3
Topsoil Strip	£ 5/m^3
Topsoil Spread	£ 5/m^3
Grass Seeding	£ 0.4/m^2
Additional Costs (2007)	
General Items	+40%
Fees	+20%
Contingencies	+20%

Table 14.1 – Criteria used to derive the Cost of Flood Defence Improvement Works in West Lindsey.

14.6 Table 14.2 (next page) identifies the principal locations and the cost based on the above prices of raising the defences to the required standard of protection for each of the Main Rivers in West Lindsey.

River	Bank	Location of Embankment(s)	Cost
Trent	Right	River Eau to Susworth	£ 60,000
		Morton Wharf to Bowling Green Lane	£140,000
		A156 to Gainsborough Railway Bridge	£150,000
		Gainsborough Railway Bridge to Lea Sewage Works	£190,000
		Lea Sewage Works to Knaith Hall	£4,300,000
		Knaith Hall to Redhill	£860,000
		Burton Chateau to North of Trent Port	£2,500,000
		Trent Port to Brampton	£1,300,000
		North of Torksey Oil Terminal	£240,000
		Torksey Viaduct	£ 50,000
		South of Torksey to Torksey Cut	£280,000
		Torksey Cut to Dunham Bridge	£5,600,000
		North Clifton Sluice to District Boundary	£1,600,000
Ancholme	Left	Redbourne River to Sallowrow Drain	£430,000
	Right		£420,000
	Left	Sallowrow Drain to Blackdyke Drain	£320,000
	Right		£500,000
	Left	Blackdyke Drain to Browns Bridge	£520,000
	Right		£300,000
Rase		North Reservoir Embankment	£260,000
		South Reservoir Embankment	£ 66,000
Barlings Eau	Left	Witham Confluence to Stainfield Beck	£300,000
	Right	Witham Confluence to Short Ferry Bridge	£ 82,000
		u/s Short Ferry PS to Barlings Abbey	£390,000
		Barlings Abbey to Falconry Centre	£800,000
		Caravan park to d/s of Langworth Gauging Weir	£800,000
River Till	Left	Washland Control Sluice to 2nd Broxholme Bridge	£310,000
	Right		£190,000
	Left	2nd Broxholme Bridge to upstream of the Reservoir	£ 38,000
	Left	Upstream of the Reservoir to Stow Bridge	£280,000
	Right		£270,000

Table 14.2 – Summary of Costs of Raising the Standard of Flood Defences in West Lindsey.

14.7 Based on the figures in Table 14.2, the total cost to improve the defences to the required standard of protection throughout the whole of West Lindsey District would be approximately £24,000,000. This is a conservative estimate. Specific requirements at individual locations and the extent of extra work (i.e. floodwall instead of floodbank) to protect urban areas are likely to increase costs further.

14.8 Along the River Trent, the standard of protection of the earth embankments downstream of Gainsborough is, on average, above the required standard of 1 in 200 years. Isolated lengths of the earth embankments upstream of Gainsborough do not meet the required standard as shown in Table 14.2. It should be noted that the standard of protection of the embankments that protect urban areas is higher than those which protect agricultural land. (Some of this agricultural land, for example Lea Marshes, is designed to flood during flood events in the river.)

14.9 Along the River Ancholme, the Agency's NFCDD shows that the river is embanked until Browns Bridge. Therefore the costs of raising the standard of the defences have only been calculated to this location for both sides of the river.

14.10 The River Rase is not protected by embankments for the whole of its length. The cost of raising the height of the Flood Storage Reservoir embankments upstream of Market Rasen to provide protection from a 1 in 75 year event to a 1 in 100 year event has been calculated.

14.11 The standard of protection along the River Witham is for a 1 in 10 year return period flood event. As the defences have recently been designed for this minimum return period, the cost of raising the level of the defences to the 100 year standard has not been calculated.

14.12 The Barlings Eau is embanked on at least one side of the Eau until Langworth. The cost of increasing the standard of defences on each of the banks has been calculated separately.

14.13 The standard of protection along the Fossdyke Canal is greater than a 1 in 100 year event. The Upper Witham draft model results showed that the level in the Canal during the 100 year event did not reach bankfull. An assessment of raising the standard of protection has therefore not needed to be undertaken.

14.14 Along the River Till the majority of the earth embankments are at the required standard of protection. The flood embankments along the side of the flood storage reservoir have been assessed to raise the standard of the defence to the 1 in 100 year level even though the embankments have been designed to the 1 in 10 year standard.

14.15 The practical constraint of raising the standard of defences for the whole of the Main Rivers is of course the cost. However, by confining the water to the channel, in accordance with ‘Making Space for Water’, storage of excess water might have to be provided somewhere else. This would most likely incur an additional cost. The individual location requirements and extent of works required to protect a certain area are also likely to increase costs significantly.

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Planning Policy and Flood Risk

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15 Planning Policy and Flood Risk

15.1 In June 2006 the West Lindsey Local Plan First Review (Ref 19) was adopted by the Council. The Local Plan is part of the District Council's development plans which outline the spatial framework for future land use within West Lindsey up to the year 2016 and it is the primary consideration in decision making on individual planning applications. It takes into consideration the Regional Spatial Strategy for the East Midlands as well as the Lincolnshire Structure Plan Review.

15.2 In the Local Plan the housing requirement was less than in the Lincolnshire County Annual Requirement. This meant that the housing requirement for the plan period was 5,250 additional dwellings in the District. From this figure the Plan splits the District into sub-areas: Towns (Gainsborough, Market Rasen, Caistor), the Lincoln Policy Area, and Rural. The numbers of dwellings allocated to each area are shown in Table 15.1.

Sub Area	Number of Dwellings
Gainsborough	2,001
Market Rasen (inc. Middle Rasen)	771
Caistor	398
Lincoln Policy Area (West Lindsey Portion)	564
Rural	1,516
Total	**5,250**

Table 15.1 - Overall Housing Allocation for the Local Plan Period.

15.3 The Local Plan describes in Policy Strategy 3 a settlement hierarchy stating that the main focus of development should be towards main settlements which have the facilities and services to sustain new residents. The hierarchy enables new development to be appropriately located.

15.4 West Lindsey Policy Economy 12 also describes improving road network links in Gainsborough and Caistor. Access from Gainsborough to the motorway network and improved access to the industrial areas of Caistor are seen as desirable to improve the District's accessibility. However, no routes have been identified and no road schemes have been proposed in the Lincolnshire Local Transport Plan.

15.5 Policy Strategy 15 focuses upon employment allocation sites within the District. Gainsborough (Heapham Road), Saxilby Enterprise Park, Brookenby Technical Park and Caistor (North Kelsey Road) sites are the largest sites proposed. One of the main objectives of the Local Plan is to ensure that the Heapham Road employment site achieves a 50% occupancy target by 2016. However, increasing the amount of industrial development has the potential to increase the risk of flooding from surface water.

15.6 Review of the Local Plan (Ref 19) does provide a general indication of where future development is likely to be concentrated, but given the scale of the development the impact is potentially of major significance. However no mention is made regarding the impact on flood risk. Policy SUS 14 in the Local Plan does make reference to flood risk areas, but not specifically.

15.7 It is probable that the District Council will as a matter of course be concerned to ensure that these major urban developments incorporate sustainable urban drainage systems (SUDS) (Ref 20) and that appropriate physical features, such as adequate runoff retention storage and flow retarders, are included in the design of these systems. These features are necessary in order to limit the surface water runoff from the newly impermeable areas created by the urban developments to the rates and volumes of runoff which would have been generated by those "greenfield" areas prior to urbanisation.

15.8 Although SUDS are now routinely included in the design of new urban drainage systems in Britain, they have not been in use for long enough or widely enough to ascertain how effective they are at the catchment scale in controlling runoff from urban areas. Even if SUDS are to become a mandatory feature of all urban development, they are designed to attenuate runoff from storm events of a specific return period, or less. The attenuation of runoff from storms greater than that for which the drainage system was designed will only be partial. It is therefore inevitable that, even with the universal use of SUDS, future urban development will result in greater runoff volumes and higher flood peaks than was hitherto the case.

15.9 This phenomenon, combined with the potential increase in storm runoff and flood flows resulting from climate change, will inevitably have an adverse effect on flood risk in river catchments subject to large scale urbanisation, particularly where that urbanisation takes place in the headwaters of the catchment. However, given the proposed pattern of development, this situation should not be a major problem in West Lindsey.

15.10 The increased flood risk from urban development may prove to be relatively small in West Lindsey, but this cannot be guaranteed as it will depend on the collective efficiency of numerous local or site-specific runoff retention works implemented as development progresses over a wide area. It is essential to closely monitor flood magnitude and frequency trends along the Main Rivers to determine whether these measures are proving effective at the catchment scale for both moderate and high return period flood events.

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Guidance For Planners and Developers

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16 Guidance For Planners and Developers

16.1 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.

16.2 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.

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

16.4 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

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

16.6 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.

16.7 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

16.8 The best way to avoid flood risk is to locate the development outside areas of flood risk i.e. Flood Zone 1.

Site Layout

16.9 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.

16.10 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.

16.11 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.

16.12 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.

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

16.14 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 exceedence of piped systems. It also enables these to be safeguarded for the future by protecting them from development and other obstruction.

16.15 Development proposals should design for key flow routes.

16.16 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

16.17 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

16.18 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.

16.19 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.

16.20 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

16.21 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.

16.22 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

16.23 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

16.24 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

16.25 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.

16.26 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.

16.27 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.

Flood resistance and resilience

16.28 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.

16.29 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.

16.30 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.

16.31 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.

16.32 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.

16.33 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*).

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Sustainable Drainage Systems

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17 Sustainable Drainage Systems

17.1 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 harmful effects:

- Run-off 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 run-off 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

17.2 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.

17.3 Planning Policy Statement 25 emphasizes 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.

17.4 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.

17.5 West Lindsey 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.

17.6 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.

17.7 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.

17.8 The elements of the Management Train are outlined below.

Source Control

Green roofs and rainwater re-use

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

17.10 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

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

17.12 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

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

17.14 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

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

17.16 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

17.17 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

17.18 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.

17.19 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

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

17.21 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

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

17.23 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

17.24 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.

17.25 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.

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

Adoption and Maintenance

17.27 For SUDS to provide consistent and effective long-term attenuation of runoff from the 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.

17.28 If widespread urban development takes place it could have a material effect on fluvial flood risk in West Lindsey unless SUDS are fully incorporated into the surface water drainage systems of all new development.

17.29 Following the publication of the Pitt Review, the Government made a commitment to resolve some of the barriers to SUDS. 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 development which will go some way to reducing the impact of new developments on surface water quality and flood risk.

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Conclusions

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18 Conclusions

18.1 Local Planning Authorities are required to use the Flood Zone Maps, provided by the Environment Agency which show inherent flood risk (i.e. without defences), when applying the sequential test. Where a LPA cannot allocate all development in flood zone 1 they will need to apply the exception test and therefore need estimates of actual' flood risk within their District. Hence the need for a Strategic Flood Risk Assessment to provide these estimates.

18.2 Studies and investigations undertaken in connection with this Report have identified the various potential sources of tidal and fluvial flood risk that could cause flooding in the District of West Lindsey. The principal source of flood risk for most of West Lindsey is from the Environment Agency's Main Rivers. Taking natural and man-made topographical features into consideration and utilising hydraulic modelling results from other catchment studies, the areas of principal flood risk have been divided into areas considered to fall within the four categories of actual flood risk (i.e. with existing flood defences taken into account) as defined in this Report.

18.3 This has enabled a set of ten 1/25,000 scale maps covering the whole of West Lindsey (Figure 9.1) to be prepared, showing an estimate of actual flood risk at any point within the District. These maps are a starting point for the District Council in determining both the actual and relative degree of flood risk to which different areas of the District may be subject, thereby enabling informed planning decisions, both strategic and site-specific, to be made and justified with confidence.

18.4 According to the predictions in PPS 25, fluvial flood flows will increase by 20% in the next hundred years and sea level is predicted to rise over one metre as a result of climate change. Unfortunately none of the hydraulic models of the major rivers in West Lindsey had been run to include the PPS 25 predictions. As Gainsborough, the main town in West Lindsey, is situated adjacent to the River Trent the hydraulic model was therefore re-run to incorporate the climate change predictions in PPS25. The results, illustrating the effect of climate change by the year 2115, are mapped in Figure 9.2.

18.5 In addition to the general flood risk maps described above, this Report also contains detailed flood risk assessments for four large study areas identified by the District Council. For each study area the flood risk assessment includes a description of the extent of those parts of the study area within each of the four flood risk zones defined in PPS 25. Each assessment is accompanied by a 1/10,000 scale plan of the study area showing the main flood risk sources and the salient topographical and drainage features likely to influence flood risk within that area.

18.6 Detailed consideration of the four study areas has revealed that future development in each of the study areas would not significantly increase the flood risk in the study area itself or to downstream areas. The study areas are already extensively urbanised and further development or redevelopment, providing the existing surface water drainage systems is adequate, should not impact significantly on flood risk. There is however surface water drains discharging to the River Rase in Market Rasen where flood risk could potentially increase if the flow in those drains increased. It should be emphasised that development proposals should aim to reduce risk wherever possible.

18.7 In order for WLDC to apply the sequential test within the study areas, knowledge of flood depths and velocities are required. 2D breach analysis modelling using the software package Tuflow was undertaken at three locations along the right bank of the River Trent at Gainsborough and at one location on the left bank of the River Witham at Bardney.

18.8 No additional modelling was undertaken at Market Rasen, even though it is a key development area, as no up-to-date river model results were available at the time of writing this report, although a hydraulic model of the River Rase and the River Ancholme is in the process of being approved by the Environment Agency. When these model results become available they will need to be incorporated in the SFRA.

18.9 This Report also assesses the adequacy of the surface water drainage regime in Gainsborough. The area most significantly at risk of localised surface water flooding is the downtown area of Gainsborough, Church Street in particular. Further detailed investigation is required into the cause of and solution to this problem.

18.10 It is hoped that this Report will form a sound and reliable basis for West Lindsey District Council to make informed and confident spatial planning decisions where flood risk is an issue, both at the strategic and site-specific levels, thereby reducing the time taken to reach decisions and making better use of the resources employed in reaching those decisions.

Recommendations

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19 Recommendations

19.1 In accordance with the findings of this study and the conclusions reached in Section 16 of this Report the following recommendations are made:

- West Lindsey District Council should:

  Use the Flood Zone maps when applying the sequential test for future land allocations.

  For Gainsborough and Bardney, use the flood hazard maps to inform the application of the sequential approach where development is required in flood zone 3 to steer development to the areas at lowest flood risk.

  For other areas use the Strategic Flood Risk Maps prepared for the District (Figure 9.1 in this Report) to inform the application of the sequential approach where development is required in flood zone 3 to steer development to the areas at lowest flood risk..

- The flood risk assessments made for the four study areas identified in this Report and the associated flood hazard maps should be used to inform the exception test

- Detailed planning guidance for developers on the use of this SFRA for planning applications to be developed by WLDC

- Hydraulic modelling of the surface water sewers in the downtown area of Gainsborough should be undertaken, in conjunction with Severn Trent Water, in order to determine their hydraulic capacity, the degree of flood risk to neighbouring property posed by those sewers in a major storm event, and the scope of the works required to improve the capacity of those sewers to an acceptable standard.

- The District Council should be fully aware of the potential impact on flood risk to downstream areas resulting from the raising of the defences along a particular stretch of Main River.

- Because of the importance of ensuring that any SUDS installed in connection with a large scale urban development are properly inspected and maintained over the life of the development, the District Council may, de-facto, find itself faced with this responsibility. This possibility should be anticipated in each case at the planning stage and, if applicable in that case, provision made at that stage for the funding of the future inspection and maintenance of the installation by the Council.

- When the results of the hydraulic modelling of the River Rase and River Ancholme become available they should be incorporated into the SFRA.

- WLDC should take account of recent and emerging policies and plans such as:

  Catchment Flood management Plans

  Water Framework Directive

  Draft Flood and Water Bill

- WLDC to make emergency planners aware of this SFRA and input into future reviews.

- WLDC should consider the need for Water Cycle Studies and Surface Water Management Plans to inform their development proposals, particularly for Gainsborough.

- The SFRA should be reviewed every five years or when key changes occur in the District or if there has been a major flood event. In particular the next review should reconsider the use of the terms actual flood risk and flood risk categories.

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