Kings Lynn & West Norfolk Strategic Flood Risk Assessment (2007/8 Revision)

Final Report

Kings Lynn & West Norfolk Borough Council

December 2008

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Executive Summary

The Department for Communities and Local Government's Planning Policy Statement 25 entitled "Development and Flood Risk" outlines how flood risk issues should be addressed in both Regional and Local Authority development plans as well as in the planning guidance issued to developers by planning authorities. The Planning Policy Statement (and its accompanying Practice Guide) also provides guidance on how flood risk assessments should be undertaken at regional, district (strategic) and development site level.

Bullen Consultants Ltd, now part of Faber Maunsell, were originally commissioned by Kings Lynn & West Norfolk Borough Council in April 2003 to undertake a Strategic Flood Risk Assessment of the Borough based on a Brief issued by the Borough Council. The purpose of that study was to provide a reference and policy document to inform the Borough Council's Local Plan. Kings Lynn & West Norfolk was one of the earliest local planning authorities in the country to undertake a strategic flood risk assessment and the Kings Lynn & West Norfolk Strategic Flood Risk Assessment Report was published in August 2005.

The 2005 Strategic Flood Risk Assessment identified and mapped the areas of actual flood risk over the whole of the Borough within the categories defined in the then current Planning Policy Guidance Note 25, which has since been superseded by Planning Policy Statement 25. More detailed flood risk assessments were also carried out for a number of study areas within the Borough.

The flood mapping methodology employed in the 2003/5 study incorporated that used by the Environment Agency for their Humber Estuary study. This methodology utilised the one-dimensional hydraulic modelling of breaches in raised flood defences to determine the extent of flood envelopes for flood events of return periods corresponding to the Flood Risk Zones defined in Planning Policy Guidance Note 25.

Since 2005, advances in hydraulic modelling techniques have seen one-dimensional methods superseded by more sophisticated two-dimensional methodologies and this has resulted in more precise mapping of flood risk. Furthermore, since 2005 the Environment Agency has completed a ground level survey of a significant area of the Borough using airborne light detection and radar (LiDAR) techniques which has enabled a much more accurate representation of local topography to be incorporated into the hydraulic modelling procedures.

The Environment Agency was therefore keen to see Kings Lynn & West Norfolk's original Strategic Flood Risk Assessment and associated flood risk maps revised and updated to incorporate two-dimensional modelling techniques and the LiDAR survey data as well as the revised predictions of the effect of climate change on tide levels and flood flows in the new Planning Policy Statement 25, which had by then become available. Consequently a Brief was drawn up jointly by the Borough Council and the Environment Agency in May 2007 and Faber Maunsell were asked to carry out the work of revising and updating the original strategic flood risk assessment as described in the Brief. The Borough Council took the opportunity of including in the Brief a more detailed study of the principal urban areas within the Borough.

The results of the revised and updated Strategic Flood Risk Assessment are presented in this Report as a set of eleven 1/25,000 scale maps covering the whole of the Borough and showing the actual flood risk at any point in one of the three categories of flood risk defined in Planning Policy Statement 25, taking into account the effect of the existing flood defences in reducing flood risk. Two separate sets of maps have been produced; one illustrating the current levels of actual flood risk and one showing estimated levels of actual flood risk in the year 2115, allowing for the predicted effects of climate change. The Report also includes a set of strategic maps showing the extent of the Hazard ('Rapid Inundation') Zone derived using criteria stipulated by the Environment Agency.

The project was carried out in collaboration with the Environment Agency's Anglian Region and utilised detailed sewerage plans of urban areas in the Borough provided by Anglian Water Services. A draft of this Report was submitted to the Agency for their comments and observations and, following discussions 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.

1 Introduction

1.1 Faber Maunsell were commissioned by Kings Lynn & West Norfolk Borough Council on 20th June 2007 to undertake a Strategic Flood Risk Assessment of the whole Borough (Figure 1.1). The task included the following principal components:

- To identify and map the generalised flood risk zones as defined in Planning Policy Statement 25 over the whole of the Borough.
- To undertake more detailed flood risk assessments of Kings Lynn and other key urban areas within the Borough.
- To model the probability and consequences for a range of flood defence breach scenarios throughout the Borough.

1.2 Planning Policy Guidance Note 25 ('PPG25') (Ref.1) issued in July 2001 by the Department for Transport, Local Government and the Regions expected local planning authorities to apply a risk-based approach to the preparation of their development plans in respect of possible flooding. Appendix F of PPG25 contained specific guidance for planning authorities and those working on their behalf on the methodology to be used in undertaking a flood risk assessment.

1.3 In December 2006 PPG25 was superseded by the Department for Communities and Local Government's Planning Policy Statement 25 ('PPS25') (Ref.2). PPS25, supplemented in June 2008 by its Practice Guide (Ref.2a), presents somewhat more rigorous and prescriptive recommendations for assessing and dealing with flood risk than were contained in PPG25. This study has therefore been undertaken in accordance with the provisions of PPS25, the implications of which are discussed in greater detail in the next Section.

1.4 The original Kings Lynn & West Norfolk Strategic Flood Risk Assessment Report (SFRA), which had been approved and 'signed off' by the Environment Agency, was published in August 2005 (Ref.3a) and has subsequently been used to inform the Council's planning policies. Kings Lynn & West Norfolk Borough Council had been one of the earliest Local Planning Authorities (LPAs) in Great Britain to commission a strategic flood risk assessment.

1.5 The modelling of the flood defence breach scenarios undertaken in the original 2003/5 study had been undertaken using a one-dimensional hydraulic modelling methodology stipulated by the Environment Agency. At that time two-dimensional (2D) hydraulic modelling techniques for the analysis of flood defence breaches were still in the developmental stage. However, in the past three years 2D modelling techniques have become more generally available and are now routinely employed, where applicable, in strategic flood risk assessments.

1.6 Because of the introduction of PPS25 and advances in hydraulic modelling techniques since the publication of the original Kings Lynn & West Norfolk SFRA Report, the Environment Agency was keen to see the SFRA updated, using a 2D modelling methodology to revise the assessment of the flood defence breach scenarios. Two dimensional breach scenario modelling requires a precise ground surface model of the land at risk of flooding, and whereas in 2003/5 there had been limited detailed topographic map coverage (LiDAR) of the Borough available, the Environment Agency's national programme of LiDAR surveys has since been extended to include much more of the Borough and LiDAR coverage of almost all of the flood risk areas of the Borough is now available, making the use of 2D breach scenario modelling feasible.

1.7 In early 2007 the Environment Agency entered into discussions with Kings Lynn & West Norfolk Borough Council and agreement was reached on the need for a revised and updated SFRA which would be used to inform the Core Strategy of the Borough Council's Local Development Framework. Work on the Core Strategy had started in 2004.

1.8 The Environment Agency and Borough Council in consultation with Faber Maunsell (as successors to Bullen Consultants) then drew up a Brief for the project. This Brief, which was finalised in May 2007, is included as Appendix A. The five principal objectives of the project as stated in the Brief can be summarised as follows:

- Evaluate the data used in the original SFRA to ensure that the best available data is still being used.
- Use an appropriate number of flood defence breach scenarios to re-evaluate flood risk throughout the Borough, both at present and in the year 2115.
- Assess the nature, source, depth, velocity, impact and residual risks of potential flooding within the Kings Lynn urban area.
- Present a detailed assessment of flood risk for eleven study areas in the three principal urban areas of the Borough.
- Offer general conclusions as to the nature and degree of present flood risk (including any deficiencies in defence standards and physical conditions) and how the risk is likely to develop over the next hundred years.

1.9 The Brief divided the study into two parts. The first part was the assessment and mapping of actual flood risk over the whole of the Borough for both fluvial and tidal flood risk areas in accordance with the flood risk categories in PPS25. Separate maps would also include hazard (rapid inundation) zones where there was considered to be a risk to life and limb in the event of a breach in a raised tidal or fluvial flood defence.

1.10 The second part was the more detailed assessment and mapping of actual flood risk in the key urban areas of the Borough. These were defined in the Brief as Kings Lynn itself, Downham Market and Hunstanton. Maps showing the locations of the individual study areas in these three locations are presented in Figures 1.2.1, 1.2.2 and 1.2.3. The Kings Lynn urban area has been divided into eight study areas and the Downham Market urban area into two study areas. Hunstanton constitutes a single study area. These study areas are listed in Table 1.1.

Ref. Number	Development Area	Area (ha)
	Kings Lynn	
KL1	South Lynn	471.3
KL2	West Lynn	221.6
KL3	Historic Core (Old Lynn)	168.6
KL4	North Lynn	131.4
KL5	Gaywood	751.1
KL6	Hardwick	402.4
KL7	Eastern Expansion Area	231.4
KL8	North and South Wootton	115.0

Table 1.1 (part 1) Study Areas in Kings Lynn & West Norfolk

Ref.Number	Development Area	Area (ha)
Downham Market		
DM1	Downham North West	85.1
DM2	Downham South West	58.6
Hunstanton		
HN1	Hunstanton	229.4

Table 1.1 (part 2) Study Areas in Kings Lynn & West Norfolk

1.11 The 2005 Kings Lynn & West Norfolk Strategic Flood Risk Assessment and the Environment Agency's latest Flood Zone Maps (see Section 2) have been used as the starting point for this study. These have been supplemented by other information supplied by the Borough Council, the Environment Agency, Anglian Water Services, Internal Drainage Boards and other sources. Due consideration has also been given to the Environment Agency's guidance notes on flood risk assessment issued to Local Planning Authorities.

1.12 The methodologies used to carry out the revision and updating of the strategic flood risk assessment and the individual flood risk assessments for the study areas, together with the results obtained, are described in detail in Section 5 of this Report. The results are also presented as a series of eleven 1/25,000 scale Strategic Flood Risk Maps for both present day and 'with climate change' conditions and a series of eleven 1/25,000 scale Hazard Zone Maps, together with more detailed and larger scale flood risk plans for each of the urban study areas listed in Table 1.1.

1.13 This Report should be seen as an updated and revised version of the original 2005 SFRA Report. This Report takes the 2005 Report as its starting point and should be read in conjunction with the 2005 Report. As much of the material contained and assessments made in the 2005 Report are still valid, it is considered unnecessary to duplicate them in this Report which will concentrate principally on those issues where significant revisions, amendments or updating has taken place. The conclusions and recommendations in the original Report should still be regarded as valid, except where they have been specifically superseded or revised by the results, conclusions and recommendations contained in this Report. **It should, however, be emphasised that the improved flood risk assessment methodology used in this study means that the revised Strategic Flood Risk maps in this Report entirely supersede the Strategic Flood Risk maps contained in the original 2005 Report.**

1.14 The conclusions reached in the 2005 Report that are considered to be still applicable as they appear in that Report or are equally applicable to this Report are those in paragraphs 11.3, 11.4, 11.5, 11.10 and 11.12 of the 2005 Report. The remaining conclusions have been superseded by those in this Report. The 2005 conclusions are given in full in Appendix B.

1.15 The fifth, sixth, seventh, eighth and tenth recommendations made in the 2005 Report are considered to be still applicable as they appear in that Report. The first recommendation in the 2005 Report is applicable with the deletion of the word "forthcoming" and the fourth recommendation with the words "fifty years" replaced by "hundred years". The 2005 conclusions are also given in full in Appendix B.

1.16 The original SFRA Report was accompanied by a separate and more detailed Report entitled "Strategic Flood Risk Assessment – Hunstanton / Snettisham Study" published in December 2003 (Ref.3b) based on a study of the seasonal variations in tidal flood risk along the eastern shoreline of the Wash. This study utilised two-dimensional hydraulic modelling to investigate the impact of breaches in the sea defences on the immediate hinterland and its findings have not been invalidated by this Report and should be taken in conjunction with it.

1.17 This document has been prepared by Faber Maunsell Ltd ("Faber Maunsell") for the sole use of the client, Kings Lynn & West Norfolk Borough Council ("the Council") as a revision and updating of the Council's original Strategic Flood Risk Assessment and as a flood risk assessment of eleven study areas in the Borough of Kings Lynn & West Norfolk for the Council, in accordance with generally accepted consultancy principles, the budget for fees, and the terms of reference agreed between Faber Maunsell and the Council. Any information provided by third parties and referred to herein has not been checked or verified by Faber Maunsell unless otherwise expressly stated in the Report. No third party may rely upon this document without the prior and express written agreement of Faber Maunsell.

2 Flood Risk

2.1 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. Both types of flood risk are prevalent in the Borough of Kings Lynn & West Norfolk although tidal flood risk is considered to be the more critical.

Planning Policy Statement 25

2.2 Planning Policy Statement 25 (PPS25) which superseded PPG25 in December 2006, defines three distinct zones of flood risk, one of which is sub-divided. These zones are based on the inherent degree of flood risk (i.e. ignoring the presence and effect of existing flood defences or other man-made obstructions to flood flows) to which an area of land is currently subject. These three Flood Zones, numerically equivalent to those used in PPG25, are given for both fluvial and tidal flood risk in Annexe D (Table D1) to PPS25 and are summarised in Table 2.1 below :-

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

Table 2.1 - PPS25 Flood Risk Zones

Note: The Functional Floodplain also includes land which is designed to flood (i.e. washlands or flood storage areas) in an extreme 0.1% annual probability (1 in 1000 years) flood event.

2.3 Planning Policy Statement 25 was supported by a Practice Guide Companion issued as a draft consultation document in February 2007 (Ref.2b). The draft document was subsequently replaced by a definitive Practice Guide in June 2008 (Ref.2a).

2.4 One major difference between PPG25 and PPS25 is that the latter sub-divides Zone 3 into Zones 3a and 3b, as opposed to the three undivided zones used in PPG25. Land on which the annual probability of flooding is greater than 5%, or where water has to flow or is stored in times of flood or is designed to flood in an extreme (0.1%) flood, or at another probability agreed between the LPA and the Environment Agency, is now designated as Functional Floodplain, hitherto unquantified and defined simply as "the unobstructed or active areas where water regularly flows in times of flood".

2.5 Another major difference between PPG25 and PPS25 is the introduction of a Flood Risk Vulnerability classification in PPS25. This classifies development into five categories according to its assumed vulnerability to flooding. These five categories (detailed in Table D2 in PPS25) are Essential Infrastructure, Highly Vulnerable, More Vulnerable, Less Vulnerable, and Water-Compatible Development. Each of these categories is then considered to be compatible with certain flood risk zones but not with others (Table D3) although PPS25 introduces the “exception test” to provide some flexibility in deciding whether a particular development would be acceptable in (e.g.) Zone 2 rather than Zone 1.

2.6 The PPS25 flood risk zones give a broad indication of flood risk. However, most areas which fall within the High Probability Zone (Zone 3) are on fluvial or tidal floodplains and many such areas already enjoy a substantial degree of protection from established flood defences. The actual degree of flood risk to which these areas are subject may well be significantly less than that implied by their PPS25 classification, provided that those defences are maintained at their current standard.

2.7 PPS25 requires Local Planning Authorities (LPAs) 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. Since the introduction of PPS25 the flood risk vulnerability classification and the exception test give LPAs a greater degree of flexibility in allocating development within flood risk areas.

2.8 It is obvious that potential development areas in different parts of Zone 3a may be at very different risks of flooding. For example, whereas the annual probability of flooding in one area may be as high as 4% (1 in 25 years) the probability in a neighbouring area may be as little as 1% (1 in 100 years), yet both are in Zone 3a. In a defended area the probability of fluvial flooding may well be substantially less than 1% yet the area will still fall within Zone 3a. The planning authority must therefore be able to rank development areas according to actual flood risk.

2.9 It is, however, necessary to review the development of strategic flood risk assessment and mapping in England in order to put the current situation in context. This will be done in remainder of this Section.

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 Agency’s Indicative Floodplain maps.

2.11 "Indicative Floodplains" were defined by the Environment Agency as being those areas where flooding had been known to occur which or which would naturally (i.e. without flood defences) be subject to fluvial flooding, on average, at least once every hundred years, or to tidal flooding at least once every two hundred years.

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 in the form of compact discs (CDs).

2.13 The shape and extent of the floodplain shown on the IF maps were based on a combination of modelled and historical event information and could not therefore 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 (Ref.4). The Environment Agency readily admitted that such anomalies existed and as better modelling or new flood event records became available this information was used to modify and update the IF maps.

2.14 The Indicative Floodplain maps have been superseded by the Environment Agency's Flood Zone Maps which are described in the following paragraphs.

Flood Zone Maps

2.15 Following a comprehensive tidal and fluvial flood risk mapping exercise carried out across the country, during Summer 2004 the Environment Agency issued to each Local Planning Authority in England and Wales a set of Flood Zone Maps in electronic format covering the whole of that authority's area.

2.16 The Flood Zone (FZ) maps were prepared using a nationally consistent methodology using a digital terrain model and flood routing techniques for the determination of flood risk zones for both tidal and fluvial flooding. Whereas the IF maps showed only the indicative floodplain, which corresponded generally to PPG25 Flood Risk Zone 3, the FZ maps show both PPG25 Flood Risk Zones 2 and 3. The FZ maps also exclude the effect of existing flood defences, but go further than the IF maps in removing the effects of de-facto defences such as road and railway embankments, major artificial drainage channels etc. These maps therefore show a 'worst case' scenario, the inherent flood risk which, in defended areas, may be significantly greater than the actual and greatly reduced risk of flooding.

2.17 The Flood Zone maps, like the earlier Indicative Floodplain maps, are based on OS 1/10,000 scale mapping but, unlike the IF maps, the FZ maps are not limited to Main River floodplains but include the floodplains of all watercourses with a catchment area of more than 3 sq.km.

2.18 The existence of the 1/10,000 scale Flood Zone maps is not publicised by the Environment Agency and hence they are not readily accessible to the general public or those wishing to undertake detailed flood risk assessments. Nevertheless, the Environment Agency will on request provide excerpts from the FZ maps for specific locations and, in some cases, those wishing to consult the FZ map for a particular area may be able to do so through the relevant Local Planning Authority.

The Flood Map

2.19 In October 2004 the Environment Agency issued a further set of flood risk maps ("the Flood Map") covering all of England and Wales. This map, based on the OS 1/50,000 scale map, is intended for use by the general public and is available via the Environment Agency's website on the internet. The Flood Map shows the same Flood Zone envelopes as the Flood Zone Maps and is not intended to supersede the larger scale and more detailed Flood Zone maps issued to Local Authorities, but is intended to give a broad scale view of flood risk in any area.

2.20 The Flood Map shows two flood risk zones; a dark blue zone in which annual flood risk probabilities are defined as greater than 1% for fluvial flooding (>0.5% for tidal), and a light blue zone in which the annual flood risk probability is greater than 0.1%. Like the IF and FZ maps, the dark and light blue areas show the potential extent of flooding without defences but, unlike the IF maps, no distinction is made on the Flood Map between fluvial and tidal flood risk areas. Flood defences (and defended areas) are shown where those defences are less than five years old and give a 1% (0.5% tidal) standard of protection.

2.21 Users of the Flood Map 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).

The 1.3% (1 in 75 years) annual probability level corresponds to the level currently adopted by the Association of British Insurers (ABI) and not that used in PPS25.

2.22 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.

2.23 The Environment Agency updates the Flood Map 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 has been 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 yet obtain a "Low" flood risk classification.

3 Causes of Flooding

3.1 The Borough of Kings Lynn & West Norfolk encompasses a wide variety of landforms, ranging from relatively narrow stream valleys in the chalk uplands in the north east of the district, through the broader and relatively flat river valleys of the Nar and Wissey south east of Kings Lynn, to the extensive areas of fenland in the Middle Level west of the Great Ouse and the fens of the South Level in the south east of the district. Flooding in such a diverse area can therefore occur in a number of different ways, and these are described in the following sub-Sections.

3.2 The River Great Ouse, which drains an extensive upland catchment covering much of Buckinghamshire, Bedfordshire and Cambridgeshire, is one of the major rivers of Eastern England and flows from south to north through the western side of the Borough of Kings Lynn & West Norfolk. Almost the whole of the Borough south of Kings Lynn, including its tributaries, the Rivers Nar, Wissey and Little Ouse, falls within its catchment. North of Kings Lynn, the small chalk streams drain either to the Wash or to the North Sea. The drainage pattern of the Borough and its principal features are shown in Figure 3.1.

Overflowing of Watercourses

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

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

3.5 When overtopping of an embanked watercourse, such as the Great Ouse upstream of Denver Sluice, occurs, the depth of water flowing over the floodbank or floodwall will probably be small, a few centimetres at most. The bank will act like a weir and the rate of flow per unit length of bank will be relatively modest and this, provided that the duration of overtopping is limited, will limit the volume of water cascading over the defences to cause flooding within the defended area. 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 3.7 to 3.14 below.

3.6 Because high spring tides occur a number of times in any year, no significant development has taken place on land below the level of the normal high water mark on spring tides (HWMOST), but if a storm tide surge coincides with a spring tide, the flood water at the peak of the tide may reach a level of up to two metres above the high spring tide level. Such an extreme event may only occur once a century but the resultant flooding could, unless tidal flood defences exist, inundate large areas of the coastal plain upon which development directly related to the coastal or maritime economy has taken place.

Breaching of Embankments

3.7 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 river channel or source of the flooding. As the crest of the bank is washed away the flow through the small initial gap increases and a small breach is created. This becomes steadily bigger as water flows through it, eroding the sides and base of the breach, and a rapid and progressive failure of the embankment follows. Complete collapse of the bank may take only minutes. The contents of the embanked channel then pour through the breach and across the now exposed hinterland.

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

3.9 The design of a floodbank (or floodwall) incorporates a certain level of freeboard to allow for uncertainties, bank settlement, wave action, etc. but the height of any floodbank 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, **but it must be borne in mind that breaches in earth embankments can occur from causes other than overtopping and may thus have return periods significantly less than the that for which the embanked channel was designed.** This is known as “residual risk” flooding which will be defined in more detail in paras.4.15 to 4.18.

3.10 Apart from overtopping, breaches in floodbanks can occur where weak spots in the bank have been created over a long period by gradual leakage through the bank at old, forgotten structures buried in the bank such as culverts or sluices (“slackers”), or where the activities of burrowing animals such as rabbits or coypu have impaired the integrity of a floodbank. 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.

3.11 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 floodbank 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, although the defence will still have a residual risk of failure.

3.12 The breaching of tidal flood defence embankments has the same essential causes as those described above for fluvial floodbanks. There are, however, two additional factors which are specific to tidal defences and compound the risk of failure.

3.13 The first of these is the effect of severe wave action on tidal defences, though this will be of greater relevance to defences exposed to the open sea (such as those along the shores of the Wash) than those along tidal estuaries (such as the Great Ouse at Kings Lynn). Under normal tidal conditions the energy released when a wave breaks will be expended on the foreshore (beach, saltings, etc) before it reaches the defence line. Under extreme conditions, such as in a storm surge, the water level at the peak of the tide may be a metre or more higher than the highest normal spring tide. The storm waves may therefore not break until they reach the floodbank itself, the energy released when the wave breaks causing serious physical damage to the embankment.

3.14 Secondly, in a storm surge the peak tide level (as well as the wave heights) will be considerably greater than normal and large volumes of tidal water may wash over the top of the floodbank on the crest of every wave. Although this wave crest overtopping will only occur for a relatively short time at the peak of the tide, while it does occur the floodbank will be subject to severe risk of erosion, and consequent failure, even though the peak tide level itself may still be well below the top of the embankment.

Mechanical, Structural or Operational Failure

3.15 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.

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

3.17 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.

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

3.19 The risks associated with this category of failures are almost impossible to quantify, especially as experience has shown that there is a joint probability relationship between this class of failure and flooding resulting directly from extreme meteorological events. It can of course be argued that if a risk of this type was quantifiable and found to be finite then action should already have been taken to alleviate the risk. Even an assessment of relative risk for failures of this type must depend on a current and detailed knowledge of the age and condition of plant, its state of maintenance, operating regime etc at a significant number of disparate installations. Mechanical, structural and operational failures are typical "residual" flood risks which will be discussed in their local context in Section 4.

Floodlocking and Tidelocking

3.20 During a flood the water level in a river will rise above the ground level in areas defended by floodbanks or floodwalls. Surface water drainage or 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 drain or sewer.

3.21 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.

3.22 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 and the Environment Agency has stated that they are not aware of any areas in Kings Lynn itself where floodlocking occurs.

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

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

Localised Flooding

3.25 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.

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

3.27 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.

3.28 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 flood 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.

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

Critical Ordinary Watercourses

3.30 In recent years some urban watercourses considered to be particularly at risk from such blockages were designated "Critical Ordinary Watercourses" (COWs) although this designation did not have any statutory status. COWs were designated in their respective areas by Local Authorities and Internal Drainage Boards, as well as by the Environment Agency. The Environment Agency has subsequently been adopting all COWs as Main Rivers. Where a COW was separated from the previous Main River system by a length of non-Main River the intervening watercourse has also been en-mained. (A 'Main River' is any watercourse shown as such on the statutory maps held by the Department of Environment, Food and Rural Affairs and over which the Environment Agency has permissive powers to carry out works of maintenance and improvement.)

3.31 Although COWs no longer exist as such, they are still of considerable interest as they indicate watercourses which have at some time been considered by a responsible statutory authority to present actual or potential problems with flooding or impaired drainage capability. The Environment Agency has, however, stated (letter dated 9th July 2008) that there are no Critical Ordinary Watercourses in Kings Lynn & West Norfolk that have either been en-mained or are due to be en-mained.

3.32 In some areas COWs were designated by Internal Drainage Boards, but no formal designation of COWS has been made by the Kings Lynn IDB or its predecessors. The Kings Lynn Consortium of IDBs (predecessor of the Kings Lynn IDB) initially designated a number of minor drains as COWs but those designations were subsequently withdrawn.

Functional Floodplains and Washlands

3.33 Although Functional Floodplains were mentioned in PPG25 they were not precisely defined. However in PPS25, where they form the basis for Flood Zone 3b, Functional Floodplains are defined as "land where water has to flow or be stored in times of flood". PPS25 goes on to state that "SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes.)".

3.34 Land "where water has to flow or be stored in times of flood'' or land which has been ''designed to flood in extreme events" is commonly known as washland. The only washlands operated by the Environment Agency within the Borough are the Hundred Foot Washes, the strip of land between between the Old and New Bedford Rivers, and three much smaller emergency washlands near Denver Sluice associated with the Great Ouse Flood Protection Scheme. One of these is situated just upstream of Denver Sluice, between the Cut-Off Channel and the Ely Ouse. The other two are situated on either side of the Relief Channel, just downstream of Denver Sluice. It is believed that the Denver washlands have never been used since the Great Ouse Scheme was commissioned in 1964.

3.35 The Environment Agency has not designated any floodplain associated with Main River as "functional" and, as far as we are aware, there are no areas where there has been an agreement between the Agency and the Borough Council as regards alternative annual probabilities of flooding in the definition of Functional Floodplains. For the purpose of this study Functional Floodplains have been taken to be any washland or area within the Borough in which the actual annual probability of flooding equals or exceeds 5%.

4 Flooding in Kings Lynn & West Norfolk

Classes of Flooding

4.1 Potential flooding in any district (other than coastal flooding, but including flooding from tidal rivers) can for the purposes of this study be grouped into five general classes according to the predominant landform in that part of the district. These classes are outlined below.

4.2 Within the Borough of Kings Lynn & West Norfolk the types of flooding which can occur will, for topographical reasons, be limited to Classes 1, 2 and 5. Flooding of Classes 3 and 4 will not be encountered but are included for completeness.

Fenland – Class 1a

4.3 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, (cross-banks, raised river or drain banks, spoil banks, roads, railways etc.) or the edge of higher land.

Fenland – Class 1b

4.4 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 rapid inundation or hazard zone in the immediate vicinity of the breach.

Fenland – Class 2

4.5 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, though this rarely affects settlements or farmsteads which, from historical experience, have been established on the marginally higher land.

Lowland Plains – Class 3

4.6 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 type will vary in depth but arises from continuous, frontal rainfall, usually on an already saturated catchment, and it develops 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 floodbanks but these will be of modest height and, even if breached, the consequences will be very much less severe than those of Class 1b.

Upland River Valleys – Class 4a

4.7 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. 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

4.8 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 3.27.

Localised Flooding – Class 5a

4.9 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 (e.g.) 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 normally limited to a single street or small cluster of properties.

Localised Flooding - Class 5b

4.10 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 paragraphs 3.20 to 3.23.

4.11 Within Kings Lynn & West Norfolk, flooding Classes 1 and 2 would be encountered in the fens west of the Great Ouse between Kings Lynn and Wisbech, and in the fens east of the Great Ouse south of the Cut-Off Channel (the 'South Level'). Class 1 and 2 flooding could also occur in the small pocket of pump-drained fenland in the lower Nar Valley east of the A10 road. Class 4 flooding would be expected to occur in the small chalk catchments west of Kings Lynn, between the River Wissey and the North Sea coast. Class 5 flooding could occur in built-up areas, towns and large villages, anywhere in the Borough. The only places in the Borough which could conceivably be considered to be in Class 3 would be the Wissey valley upstream of Stoke Ferry or the Nar valley around Narborough, too small to be treated as a separate unit. The particular case of coastal flooding - tidal flooding of the coastal plain - is akin to Lowland Plains (Class 3) flooding but will be considered separately in Section 5.

Potential Sources of Flooding

4.12 The potential sources of flooding which are considered to present a significant strategic flood risk within Kings Lynn & West Norfolk are :-

Fluvial Flood Risk Sources

- River Great Ouse (Ely Ouse) (upstream of Denver Sluice)
- Cut-Off Channel (upstream of Denver Sluice)
- Relief Channel (downstream of Denver Sluice)
- River Little Ouse
- River Wissey
- River Nar
- Old and New Bedford Rivers
- Middle Level Main Drain (including Well Creek)
- River Burn
- Heacham, Babingley and Gaywood Rivers

Tidal Flood Risk Sources

- Wash Banks
- Great Ouse Estuary (including the Tidal River downstream of Denver Sluice and the New Bedford River upstream of Denver)
- North Sea (North Norfolk Coast from Hunstanton to Burnham Overy)
- Nene Estuary (Wisbech to the Wash)

4.13 Each of these potential sources of flooding, with the exception of the Heacham, Babingley and Gaywood Rivers, was described in detail in Section 5 of the original SFRA Report and their significance as a primary or secondary source evaluated. The Heacham, Babingley and Gaywood Rivers are now considered by the Environment Agency to be primary flood risk sources and have therefore been added to the list above. Apart form the New Bedford River, which now appears in both the fluvial and tidal lists, the significance of the other potential flood risk sources has not changed since the original SFRA Report.

4.14 This list does not include rivers which do not have significant flood risk implications for urban areas or potential allocations for development. The risk from these more minor rivers and watercourses is principally to rural land where there is unlikely to be any significant urban development.

Residual Risk Flooding

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

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

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

4.18 The failure of a major tidal outfall sluice, either a mechanical failure of the sluice gates or a collapse of the structure itself, is also a residual risk, but the likely nature of the failure would be such as to restrict the rate of inflow of tidal water through the sluice. Since there would almost certainly be a large ponded reach of river upstream of the sluice the impact of a restricted inflow over a single tide peak would be relatively minor. It would, however, be essential to take emergency action to prevent further inflows on successive tide peaks.

Flood Risk in Pump-Drained Systems

4.19 Since the original SFRA Report was issued in August 2005 the Kings Lynn IDB (as successor to the Kings Lynn Consortium of IDBs) and the East of Ouse, Nar & Polver IDB have both commissioned detailed studies of the responses of their arterial drainage systems to flood events. These studies involved hydrological and hydraulic modelling of networks of arterial drainage channels in each Drainage District and gave results in the form of flood levels for given return periods at specific locations in the network. Although these arterial drainage systems are secondary (Class 2) sources of flooding, the results of the studies are nevertheless of relevance to this SFRA.

4.20 Selected modelling results were provided by both IDBs and those results that are relevant to flood risk in Kings Lynn and West Norfolk, specifically those relating to the Gaywood River and Middleton Stop Drain in Kings Lynn, were utilised in this assessment.

Records of Flooding

4.21 Kings Lynn & West Norfolk Borough Council, the Environment Agency and the various Internal Drainage Boards within the Borough were all contacted during the original SFRA study to obtain information on flooding records and drainage problems in the Borough. Their responses received were summarised in the 2005 SFRA Report. As far as we are aware, there has been no significant or widespread flooding, either fluvial or tidal, within the Borough since 2005. This has been confirmed by the Borough Council and the IDBs.

4.22 A notable North Sea storm surge occurred on the night of 8th / 9th November 2007. The Environment Agency's tide recorder at Kings Lynn (Freebridge) recorded a peak water level of 4.66mOD between 0500 and 0515 on 9th November, about half an hour before the peak of the lunar (tide table) high tide, 3.35mOD. The tide level at Freebridge was above 4.4mOD from 0430 to 0600 hrs.

4.23 Subsequent analysis of the tide record showed that the surge at Freebridge reached its peak (1.87m above normal tide level) at 2330hrs on 8th November but there was then a secondary peak at 0345hrs (1.75m) on 9th November. The surge height exceeded 1.6m from 2130hrs on 8th November to 0430hrs on 9th November. Had the surge peak coincided with the peak of the lunar tide the water level at Freebridge would have reached 5.22mOD.

4.24 A report on the November 2007 storm surge event was subsequently published by Norfolk County Council (Ref.5). This report revealed that although minor local flooding occurred in the Great Yarmouth area and at a few locations in North Norfolk there were no recorded incidents of flooding in Kings Lynn and West Norfolk. None of the flood warning sirens in the Borough were sounded, although during the event there had been a major evacuation of people from flood risk areas in and around Great Yarmouth.

4.25 Despite the extreme weather conditions and resultant severe fluvial flooding that affected many areas of the country in June and July 2007, no serious flooding of a strategic nature was reported in Kings Lynn and West Norfolk.

4.26 Anglian Water Services are aware of localised sewer flooding problems at the following locations and investigations are ongoing to determine the sources and causes of that flooding:

Kings Lynn

Bagge Road, Hockham Street, Mayflower Avenue, Oldmedow Road and Turbus Road.

Downham Market

Maltings Lane, Oakview Drive, Paradise Road, Peverall Road and Railway Road.

Flood Alleviation Measures

4.27 Those flood alleviation measures then in existence on the principal flood risk sources in Kings Lynn and West Norfolk are all as described in the original SFRA Report issued in August 2005. Since that date there have been no significant fluvial or tidal flood alleviation schemes implemented within the Borough. The only substantial work that has since been undertaken is the Puny Drain Diversion Scheme, as part of the Nar Ouse Regeneration Area (NORA) development.

4.28 The recently completed Puny Drain Diversion Scheme involved the infilling of the Puny Drain eastwards from its tidal outfall into the Great Ouse at South Lynn to its culvert under the River Nar, and the creation of a new outfall cut from the existing Puny Drain to the Relief Channel upstream of Saddlebow. The infilling of the section of the Puny Drain in South Lynn has increased the area of land available for industrial and commercial development in the NORA project. The previous Great Ouse outfall structure has been retained in a modified form as a minor gravity outfall for local surface water drainage.

4.29 The section of the Puny Drain between the River Nar and the new outfall cut at Saddlebow has been enlarged and regraded to reverse the flow in that section of the Drain. The surface water from South Lynn which discharges into the Puny Drain east of the River Nar now provides the head of water for the southward flow in the Drain. The Puny Drain's new outfall cut has been excavated on a west to east line to the north of Clarke's Chase. The new cut passes beneath the Kings Lynn – Ely railway and a minor road before discharging into the Relief Channel just upstream of Saddlebow Bridge. As the Puny Drain no longer has an outfall to tidal waters it has been necessary to construct a land drainage pumping station on the new cut just east of the railway to provide a pumped discharge to the Relief Channel. It is understood that this pumping station is to be maintained by Anglian Water.

4.30 The new St Germans Pumping Station at the outfall of the Middle Level Main Drain to the tidal waters of the Great Ouse at Wiggenhall St Germans is part of the Middle Level Commissioners' wider drainage strategy which includes bank raising and an option of upstream flood storage. Work is currently in progress on the construction of the new pumping station, which when completed in 2009 will be the largest in Europe. Other associated works are expected to continue over the next eight to ten years. Once complete the works will provide protection against flooding from a 100 year return period event.

4.31 The new pumping station will replace the existing St Germans Pumping Station which was completed in 1934. The new station's six pumps will have a combined discharge capacity of about 100 cu.m/sec, some 40% more than the existing pumping station, to allow for the predicted increase in runoff from its extensive Middle Level fenland catchment and tide levels in the North Sea resulting from the effects of climate change over the next hundred years.

4.32 Since 2005 Anglian Water Services have undertaken one flood alleviation scheme within Kings Lynn. This scheme involved major improvements to the foul sewerage system in Queens Avenue and Portland Place in 2006/7. The scheme included a 540 cu.m off-line storm overflow storage tank and the enlarging of foul sewers. Anglian Water state that no sewer flood alleviation schemes have been carried out in Downham Market since 2005, but they are currently considering a scheme involving the main inlet sewer to the town's sewage treatment works to cater for future growth in the area. This scheme is still in its preliminary stages and no details or timescales have yet been announced.

Operational and Emergency Planning

4.33 In Kings Lynn & West Norfolk, as elsewhere in the Anglian Region, the Environment Agency has issued flood defence and land drainage emergency operational plans in conjunction with the local authority. These plans 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. In Kings Lynn & West Norfolk these plans are summarised in an annually updated leaflet entitled 'Flood Warning Information' issued jointly by the Borough Council and the Environment Agency.

4.34 Serious flooding in Kings Lynn or the surrounding area could trigger the declaration of a major incident. Should a major incident be declared, Norfolk County Council's Emergency Plan (District Integrated Flood Plan) and Kings Lynn & West Norfolk Borough Council's Emergency Plan (Flood Response Plan) would both be energised. The County Council's Emergency Plan may be found on the County Council's website, www.norfolk.gov.uk . Advice on action to be taken in the event of flooding may be found on this website and on the Borough Council's website, www.west-norfolk.gov.uk .

4.35 There are currently flood warning provisions in place for Kings Lynn and West Norfolk using the Agency's Floodline Warnings Direct system which distributes warnings by telephone (landline and mobile), e-mail, SMS text message, fax or pager. There are four flood warning states which the Environment Agency issues; Flood Watch, Flood Warning, Severe Flood Warning, and All Clear. These are described below:

a) Flood Watch – Flooding of low lying land and roads is expected

b) Flood Warning – Flooding of homes and businesses is expected

c) Severe Flood Warning – Severe flooding is expected with extreme danger to life and property

d) All Clear – No further flooding is expected and water levels will start to fall.

4.36 The network of tidal flood warning sirens in Hunstanton, Heacham, Snettisham, Kings Lynn, the Wiggenhalls (St Mary Magdalen and St Germans) Stow Bridge and Downham West is now maintained by the Borough Council or, in some cases, by the Town or Parish Council. When there is considered to be a real and impending threat of tidal flooding a sequence of five steady tones each of 30 seconds duration is sounded. No "all clear" signal is given.

4.37 Norfolk Police, assisted by local Emergency Flood Wardens, will notify residents in South Hunstanton, Heacham, Snettisham and Kings Lynn town of potential tidal flooding in those areas. In addition the Environment Agency operates a Precautionary Evacuation Notice (PEN) procedure for coastal areas at risk between Hunstanton and Snettisham and for property between the primary and secondary tidal defence lines between Hunstanton and Heacham. This ensures that the area would be evacuated safely in daylight hours before any predicted high risk flood event occurs.

5 Strategic Assessment of Flood Risk

General Methodology

5.1 For the purposes of this study, the quantitative limits of the flood risk categories used in the study to distinguish actual from inherent flood risk will correspond exactly with the four zones defined in PPS25 (Table D1 in PPS 25). This is consistent with the approach used in the original (2005) Strategic Flood Risk Assessment. Since the Environment Agency's Flood Zone (FZ) maps represent an important initial attempt to define the limit of PPS25 Flood Zones 2 and 3 (and hence the boundary between PPS25 Zones 1 and 2) they can be used as an outer limit against which to compare the detailed strategic (i.e. Borough-wide) assessment of actual flood risk within the Borough of Kings Lynn & West Norfolk.

5.2 The Environment Agency's Flood Zone (FZ) maps were compiled using the RASP methodology, a different and more systematic, nationally consistent methodology than their predecessor Indicative Floodplain (IF) maps (see para.2.16) and the anomalies encountered in the IF maps appear to have been largely eliminated.

5.3 A number of sources of data and information are available which can be used in conjunction with 2D hydraulic modelling to check and, where necessary, refine the Environment Agency's FZ maps and thus the outer limits of the High Probability and Medium Probability Zones (Zones 3 & 2). These are –

LiDAR data

The Environment Agency has established a national database of topographical spot-level data derived from an airborne laser imaging process. Contoured plots of LiDAR (Light Detection and Ranging) data are 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, even with automated filtering of the data to remove the effects of buildings, trees and other obstructions.

Even though the LiDAR data coverage does not extend over the whole country, it has now reached the point where the great majority of Zone 2 and 3 areas are included. When the original SFRA was undertaken there was limited LiDAR coverage in Kings Lynn & West Norfolk Borough. Since 2005 this situation has been remedied and when the current study was carried out the LiDAR coverage of the Borough, supplied in electronic format by the Environment Agency, was reasonably complete, apart from sizeable gaps in the South Level (the Ely Ouse / Little Ouse / River Wissey fens), fenlands to the west of the Middle Level Drain and Old Bedford River, and the uplands in the vicinity of Docking, Stanhoe and Great Bircham. The LiDAR data supplied by the Environment Agency for use in this study had a vertical resolution of $\pm$ 0.1 m and a 2m horizontal grid.

Ordnance Survey 'SAR' Data

Ordnance Survey Synthetic Aperture Radar (SAR) data coverage is obtained from aircraft or earth observation satellites. It is, however, less accurate than LiDAR data, with a vertical resolution of only $\pm$ 0.5m and a 5m horizontal grid. SAR data was utilised, where relevant, to fill the gaps in the LiDAR data coverage listed above.

Ordnance Survey Maps

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

A complete 1/10,000 scale OS map coverage of Kings Lynn and West Norfolk was provided by the Borough Council on CD which can be accessed using "Mapinfo" software. These maps are not contoured but include spot heights on roads to the nearest 0.1m (though some of these metric spot heights are conversions from earlier imperial units and are therefore only accurate to the nearest 1ft / 0.3m). The Borough Council also supplied OS mapping of the District at 1/25,000 and 1/50,000 scale, the former for use as the base mapping for the strategic flood risk maps in place of the 1/50,000 scale map base, enlarged to 1/25,000 scale, which was used as the map base in the original SFRA Report.

Environment Agency Flood Zone Maps and Flood Maps

The Environment Agency's Flood Zone Maps are based on OS 1/10,000 scale maps, and show both Flood Zones 2 and 3 and, by inference, Zone 1. Copies of the FZ maps for the whole of Kings Lynn & West Norfolk Borough were supplied 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 and the original SFRA) can be used to verify or amend the floodplain envelope. However, the absence of any significant flood events in the Borough between 2005 and 2007 meant that no additional information was available since that used in the 2004/5 study.

Topographic Divisions

5.4 In most Strategic Flood Risk Assessments, the district can be divided into a number of distinct topographic divisions, principally upland areas, major river valleys, lowland areas, and, in some districts, fenland as described in Section 4. Kings Lynn and West Norfolk is very unusual in that all these topographic divisions, with the possible exception of major river valleys, are represented in the Borough. However, much of the Borough is fenland and it should be noted that different areas of fenland can exhibit significantly different flood risk characteristics and can experience very different impacts of flooding.

Anthropogenic Influences

5.5 Man-made or anthropogenic landscape features can have a significant impact on flood risk, and there are a number of large man-made structures in Kings Lynn and West Norfolk which could have a potential impact on flood risk in the Borough 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 types of anthropogenic influence is discussed separately below.

IMPOUNDING RESERVOIRS

5.6 There are no large impounding reservoirs in the Borough which could have a significant influence on flood flows in any of the river catchments. There are a number of small flood storage lagoons in the Kings Lynn area (see Figures 7.1 to 7.11) but these do not come into the category of "large raised reservoirs" as defined in the 1975 Reservoirs Act and the flood risk associated with the failure of any of these tiny reservoirs is minimal.

5.7 There have been suggestions for the construction of a large pumped-storage reservoir for public water supply purposes in Feltwell Fen but no formal proposals have yet been put forward. This would, if built, be an embanked (bunded) reservoir with much of the water stored above adjacent ground level.

CANALS

5.8 Although many of the principal rivers in the Borough were or, in some cases, are still navigable, there are no canals in the Borough and therefore none which could have a significant influence on flood flows.

LOCKS, WEIRS & SLUICES ALONG THE RIVER GREAT OUSE

5.9 The River Great Ouse is a navigable river from Bedford to the Wash. When the river navigation was improved in the eighteenth and nineteenth centuries, navigation locks were constructed (or reconstructed) within the fenland section of the river at Brownshill, Earith (Hermitage) and at the tidal limit at Denver Sluice.

5.10 Many of the tributaries of the Great Ouse, such as the Rivers Cam (to Cambridge), Lark (to Bury St Edmunds), Little Ouse (to Thetford), Wissey (to Stoke Ferry) and Nar (to Narborough) are also navigable or have been navigable in the past. The Wisbech Canal, while it existed, provided a link between the River Nene and the Great Ouse at Salters Lode via Well Creek. Some of the principal Middle Level arterial drains in the Borough - such as the Sixteen Foot Drain (to Mullicourt Aqueduct), The Old River Nene through Outwell, and Pophams Eau are also navigable. Only the southern end of the Middle Level Main Drain itself is navigable.

5.11 The lock at Denver Sluice is integral with the tidal outfall sluice structures through which the full range of river flows is discharged. Hermitage Lock is situated at the entrance to the Old West River which links the Great Ouse at Earith with the Ely Ouse at Stretham. There is, however, very little flow in the Old West River and flood flows in the Great Ouse are diverted down the Old and New Bedford Rivers at Earith. Flows into the head of the Old Bedford River are controlled by Earith Sluice whereas there is no control of flows into the head of the tidal New Bedford River other than the state of the tide.

5.12 Flood flows in the Old Bedford River (known as the River Delph downstream of Welney) are discharged to the tidal waters of the New Bedford River at Welmore Lake Sluice. This sluice has recently been reconstructed and is a modern, well engineered structure. Flows in the northern end of the Old Bedford River (the Counter Drain) discharge to the tidal outfall channel of the Great Ouse through the Old Bedford Sluice at Salters Lode, just downstream of Denver. In major events flood flows in the Old Bedford River overspill into the Hundred Foot Washes, a flood storage area between the Old and New Bedford Rivers. Outflow from the Washes is controlled by Welmore Lake Sluice.

Flood Risk Mapping

5.13 The strategic flood risk maps illustrate the actual annual probability of flooding (taking into consideration the effect of existing flood defences) at any location in the Borough. The strategic maps are based on the assumption that if the defences are overtopped in the 100/200 year (Category 3) and/or 1000 year (Category 2) events the corresponding flood extent in that flood cell as a result of a breach will be shown.

5.14 To define whether a defence is overtopped the crest level of the defence, obtained from the Environment Agency's National Flood & Coastal Defence Database (NFCDD) was compared with the modelled or known flood level in the fluvial or tidal flood risk source. If the flood level was greater than the crest level the defence overtopped and it was therefore assumed that the defence, if 'soft', would breach automatically. A freeboard of 600mm along the coastline and 300mm along the tidal rivers was also subtracted from the crest level of the defence to take into consideration he effect of wave action. No freeboard allowance was assumed on fluvial rivers due to minimal wave action in sheltered inland locations.

5.15 The breach in the defences was modelled using the 2D modelling software Tuflow (version 2007-07-BD). A main component of the model is the terrain which is constructed from LiDAR data supplied by the Environment Agency. Any gaps in the LiDAR data were filled using Ordnance Survey SAR data. The second main component is the flood level in the principal flood risk source (i.e. river or sea) used as an input to the 2D model. The latest estimates of peak flood level for all the sources were used. A detailed technical description of the modelling methodology is given in Appendix C.

5.16 The resultant flood envelope as a result of a breach was used to represent the flood extent on the Strategic Maps. To obtain the continuous flood envelope behind a defence line the modelling process was repeated at numerous salient points along the defence line – see Appendix C for breach locations.

5.17 The two flood risk scenarios modelled in this study were as follows:-

- Flood risk at present (taken as 2008)
- Flood risk in the year 2115 (i.e. with the effects of 100+ years of climate change)

Present Day Situation

5.18 The strategic flood risk extents along tidal rivers are based on the breached flood extent where the soft defences are overtopped. It has been assumed that the hard defences in Kings Lynn do not breach as a result of overtopping, and the flood extent on the strategic maps is due to overtopping and not breaching. No modelled results were available for the 1000 year tidal river flood extent so the peak stages in the tidal rivers were obtained from the Agency's Report on Extreme Tide Levels (Ref.6) and fitted to the modelled 200-year tidal stage hydrograph.

5.19 The peak stage along the coastline was also obtained from the Report on Extreme Tide Levels (Ref 6). The peak stage was applied to a recorded tide level hydrograph at Kings Lynn (Freebridge) obtained during the storm surge event of November 2007, details of which were provided by the Environment Agency. It has been assumed that defences along the coastline between Snettisham and Hunstanton will be overtopped and breached during a 1 in 200 year event due to the nature of those defences.

5.20 The present Flood Risk Category 3 for the fluvial rivers, namely the River Nar, Old Bedford River and the Ely Ouse (including Rivers Little Ouse and Wissey), is based on the breach flood extent where the soft defences are overtopped. However no modelled results or estimates of levels were available for the 1000 year event and thus the fluvial Flood Risk Category 2 envelope could not be based on modelled breach extents but was, where appropriate, based on the Flood Risk Category 3 from the original SFRA published in 2005. Results of recent flood modelling on the Heacham River at Heacham (Ref.7) have also been used.

5.21 The results are presented as a set of eleven 1/25,000 scale Strategic Flood Risk maps (Figure 5.1). Strategic flood risk maps at 1/10,000 scale have also been produced for the Kings Lynn study area (Figure 5.1A). There were four notable gaps between the tidal and fluvial flood envelopes at the fluvial ~ tidal interface where minor rivers entered the tidal floodplain. These gaps were infilled based on ground levels in the vicinity of the river. For a more detailed explanation refer to Appendix C.

Climate Change

5.22 The climate change predictions in PPS25 (Tables B1 and B2) were used to derive corresponding estimates of the actual flood risk envelopes for the year 2115.

5.23 The modelled flood levels in the tidal rivers for the 'with climate change' scenario were based on hydraulic modelling results for Flood Risk Category 3. In the absence of 1000 year modelled results with the inclusion of climate change predictions for the tidal rivers, the predicted increase in sea level as a result of climate change was applied to the present day 1000 year stage hydrographs.

5.24 The predicted sea level rise to the year 2115 was calculated from Tables B1 and B2 in PPS25. The modelled 200-year and 1000-year tidal hydrographs for the Wash and North Sea coastlines were then reconfigured upwards to this level to produce hydrographs for the 200 year and 1000 year 'with climate change' scenarios respectively.

5.25 No 'with climate change' flood level estimates could be calculated for the fluvial rivers without re-running the existing hydraulic models with revised hydrological inputs. The 'with climate change' Flood Risk Category 3 was therefore based on the present day Flood Risk Category 2 and, due to the limited data along the fluvial rivers, Flood Risk Category 2 for the 'with climate change' scenario has not been included in the study.

5.26 These 'with climate change' results are also presented as a set of eleven Strategic Flood Risk maps (Figure 5.2) as well as a 1/10,000 scale map for the Kings Lynn study area (Figure 5.2A). For a more detailed explanation of the results refer to Appendix C.

Flood Hazard Mapping - General

5.27 In a major flood event where a river is confined within flood defences, there may be an appreciable difference between the water level on one side of the flood defence and the ground level in the defended area behind that defence. If that defence were then to fail, whether through the collapse of a floodwall or the breaching of an embankment, there would be a sudden inrush of flood water into the defended area. The velocity and depth of water cascading through the breach could, initially at least, be sufficiently great to sweep 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 equal consideration in flood risk assessment.

5.28 As flood water pours through a breach it will fan out across the hinterland behind the defences, and its velocity and depth will decrease with distance from the breach. At some distance from the breach the velocity and depth of water will have diminished to a point where an adult is capable of standing upright in the flow. This is deemed to be the outer edge of the hazard zone. The distance of this point from the defence line, and hence the width of the hazard zone, 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.

5.29 In the 2005 SFRA Report a basic one-dimensional hydraulic analysis methodology for determining hazard zone width utilising a two-parameter matrix (head of water and breach width) was used, namely that developed for the Environment Agency in connection with its Humber Estuary Shoreline Management Plan and its associated investigation of tidal flood risk along the Humber estuary (Ref.8) That methodology assumed that the critical point occurs when the product of depth (m) and velocity (m/s) reaches a value of 1.0 m^2/s (e.g. 1m deep water flowing at 1m/s, or 0.5m deep water flowing at 2m/s). Since only minimal LiDAR data coverage was available for the Borough at that that time, a simple matrix for determining the width of the hazard zone behind any raised flood defence, assuming a level hinterland, was presented.

5.30 In the present study, in addition to the Strategic Flood Risk maps the Brief required the production of maps showing the extent of Rapid Inundation (or Hazard) Zones throughout the Borough. "Rapid Inundation" Zones were defined by the Environment Agency as areas of land behind both fluvial and tidal defences within which flood flow velocities exceed 0.5 metres/second or the depth of flooding exceeds 0.25metre. Since the Environment Agency's definition makes no stipulation as to the length of time before the depth of flooding reaches 0.25m, their definition will include areas where hours or even days could elapse before that depth of flooding is reached.

5.31 The use of the term "Rapid Inundation" Zones to include such areas of demonstrably very slow inundation could be misunderstood by the general public and give rise to confusion and concern. Nevertheless, a flood depth of 0.25 metre in still water could be fatal to a child and the alternative appellation "Hazard Zones" was therefore used in this study. It should be noted that the Environment Agency's very conservative definition of the Hazard Zone results in correspondingly large and potentially misleading Hazard Zone envelopes.

5.32 Up to the 100-year (fluvial) / 200-year (tidal) situation for which the Hazard Zone was determined, in the great majority of cases the creation of a Hazard Zone would be as a direct result of a breach. Overtopping by itself would rarely result in flooding both deep and fast flowing enough to meet the Environment Agency's hazard criteria. However, in a residual risk event a flood defence could breach prematurely, well before that defence is overtopped. The "Hazard Zone" is therefore independent of the probability of flooding and, irrespective of mapping clarity considerations, should properly be plotted separately.

5.33 In order to give a realistic representation of the Hazard Zone it was assumed that the breach occurred at the peak of the flood hydrograph or tide peak. The effects of secondary and tertiary defence lines in obstructing the passage of flood water across the land surface were also allowed for.

5.34 The estimates of the present day Hazard Zone (as defined by the Environment Agency) across the Borough are shown on a set of eleven Hazard Zone maps (Figure 5.3) plotted to the same map base and scale as the Strategic Flood Risk maps.

5.35 It should be emphasised that the 'Rapid Inundation' or Hazard Zone is simply the area behind a flood defence line within which people could be at risk of drowning following a breach in that defence line. Since a breach can occur either as a result of overtopping or as a result of a premature (residual risk) failure of a flood defence the Hazard Zone is not associated with a specific probability of occurrence.

5.36 Furthermore, although the probability of a breach following the overtopping of a floodbank in (say) a 100-year event will be ten times more likely than an equivalent breach in a 1000-year event, the impact of the 1000-year event breach will not be significantly greater than that of the 100-year event breach, as the difference between the 100 and 1000-year flood or tide levels may be relatively small compared with the total head of water acting on the defence line.

Flood Hazard Mapping - Kings Lynn & West Lynn

5.37 The Brief also requires detailed modelling of the flood pathways within the town of Kings Lynn (including West Lynn), identifying maximum depths and velocities of flood water, and the duration of flooding for a 1 in 200 year event. It should be emphasised that it is very likely that at any point the maximum depth and maximum velocity of flood water will not occur simultaneously.

5.38 Three breaches were modelled in the right bank of the tidal Great Ouse at Kings Lynn and two breaches were modelled in the left bank at West Lynn. Much of the defence line within Kings Lynn consists of the walls of existing buildings and therefore the locations of the breaches were chosen at places (e.g. car parks or other open spaces) where, if a breach occurred, any resultant flood water would have a greater likelihood of inundating the town. The breaches at West Lynn were chosen along the soft defences to the north and south of the urban area as the probability of the hard defence line at West Lynn breaching is substantially less. The results are presented as two sets of three maps, Figures 5.4.1 to 5.4.3 and Figures 5.5.1 to 5.5.3. The first set relates to Kings Lynn and the second set to West Lynn.

5.39 In Kings Lynn, the flood extents as a result of a breach in the defences are limited to the streets in the vicinity of the breach location. This is due to the elevated nature of the ground compared to the 1 in 200 year peak tide level. Flood depths are mainly below 0.8m with maximum depths reaching 2m, in particular at Boal Quay and to the south of Alexandra Dock. Flood velocities are fairly slow, generally between 0.0 and 0.2 m/s, apart from at Boal Quay where the velocities reach 1 m/s.

5.40 In West Lynn, the flood extents are much more widespread. The defence breach flood extent to the north of West Lynn extends through the properties to the north of Ferry Road as far west as Bentinck Farm. The southern breach flood envelope extends between Clenchwarton Road and the river and between Main Road and West Lynn Drain. Flood depths range from 0m to 1.6m and flood velocities from 0 to 1 m/s.

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6 Assessment of Flood Risk in the Study Areas

6.1 Any useful assessment of flood risk within the eleven study areas identified by the Borough Council in Kings Lynn, Downham Market and Hunstanton (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 PPS25, both as regards to 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.

6.2 As the PPS25 flood risk zones are based on the situation that would obtain in the absence of any flood defences, it follows that within any PPS25 flood risk zone 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 PPS25 Zone 3 (High Probability) there may be areas which are protected to a higher standard than 1% (1in100 years). In these cases their actual flood risk classification will be Zone 2 (Medium Probability). In practice, this will only apply to Zone 3 since flood protection to a higher standard than 0.1% (1in1000 years) is unheard of.

6.3 The degree of actual flood risk throughout each of the eleven study areas, expressed in terms of the Flood Risk Categories defined in Section 5 (para.5.1). Within the study areas these categories have been assessed from a combination of factors, hydraulic modelling results, sources of information and engineering judgment. Flood risk in the study areas is assessed as current flood risk - no allowance can be made for enhanced flood risk within the study area which could arise as a result of inappropriate future development. If the predicted effects of climate change over the next century have been found to be sufficient to transfer a study area to a higher Flood Risk Category this will be stated in the assessment.

6.4 Flood risk sources considered in the assessment include coastal waters and all open watercourses (rivers, streams, 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. Flooding from groundwater is not considered to be of strategic significance in Kings Lynn and West Norfolk and flooding from canals is of no relevance.

6.5 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 created by the development but also from the reduction in natural floodplain storage capacity if the development takes place in a floodplain.

6.6 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 floodwall 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.

6.7 The area immediately behind the flood defence line within which a serious risk to life and limb could occur is known as the Hazard (or Rapid Inundation) Zone. The Hazard Zone and its determination have already been discussed in some detail in Section 5 (paras.5.27 to 5.36). Seven of the study areas were found to fall partly within Hazard Zones, details of which will be given under the "Flood Risk Within the Study Area" headings in Section 7 of this Report.

6.8 In a built-up area, the flow of water into the defended area behind a breach is very unlikely to conform to a uniform pattern. The actual pattern of flow through a breach and its immediate hinterland, and hence the width of the hazard zone at that point, will be distorted by the presence of buildings, walls, street furniture, parked vehicles, etc. Although strategic representations of the Hazard Zone have been derived and are shown on the Hazard Zone maps, a more precise assessment of the Hazard Zone should, where applicable, still be attempted in any site-specific flood risk assessment.

6.9 The flood risk assessments of the study areas made in Section 7 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.

7 Study Areas in Kings Lynn & West Norfolk

7.1 The location of the eleven study areas 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.

7.2 The eleven study areas range in size from 58 to 751 hectares. Apart from those in Downham Market, all the study areas are larger than 100 hectares and six of them range in size between 100 and 300 hectares. All the study areas comprise some urban built-up area and in some cases an adjacent undeveloped fringe around that urban area. Hence most of the study areas consist of a mixture of 'brownfield' and 'greenfield' land.

7.3 The eleven study areas in this Report do not correspond exactly to the eleven development areas (study areas) assessed in the original SFRA Report issued in August 2005. In particular, the size and locations of the eight study areas within Kings Lynn have changed. The most significant difference is the exclusion of the Wootton Marshes to the north of Kings Lynn and the inclusion of two new study areas. The first of these is to the south east of the Hardwick Industrial Estate and second includes the parcel of land to the west of South Wootton. Unlike the original SFRA Report, this Report does not include Terrington St Clement as a study area but now includes Hunstanton.

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

7.5 The degree of actual flood risk throughout each of the eleven study areas has been assessed from a combination of factors, hydraulic modelling, 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 one hundred years are considered to be sufficient to transfer a study area to a higher Flood Risk Category this will be stated in the assessment.

7.6 As far we are aware the situation as regards Critical Ordinary Watercourses in the Borough has not changed since the original SFRA Report was issued.

7.7 Many culverted watercourses, particularly in Kings Lynn, now form part of Anglian Water's surface water sewer network with outfalls direct to Main Rivers or IDB-maintained drains. In some areas these sewers can be of considerable size at their downstream ends and thus constitute potential flood risks over a significant area. This problem is addressed, where relevant, in the individual study area assessments and the larger surface water sewers are shown on the study area plans. A plan (or, for Hunstanton, a pair of plans) showing the principal hydrological and hydraulic features in each study area are presented as Figures 7.1 to 7.11. These plans should be read in conjunction with the appropriate Strategic Flood Risk and Hazard Zone maps.

7.8 The eleven 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 etc)

c) Flood risks within the study area

d) Flood risks to downstream areas

The detailed assessments are grouped in the three town-based geographical areas in separate Sub-Sections for Kings Lynn, Downham Market and Hunstanton respectively.

Study Areas in Kings Lynn

7.9 Eight of the eleven study areas in the Borough are in and around Kings Lynn itself. The eight study areas in the Kings Lynn group (Figure 1.2.1), ranging in size from 115 to 751 hectares, can be divided into three distinct categories. There is one entirely 'greenfield' area on the south eastern edge of the town. Then there are two largely and two partly 'greenfield' study areas on the northern, eastern and southern outskirts of Kings Lynn, and finally two 'brownfield' areas within the existing urban area. The West Lynn study area, across the Great Ouse from Kings Lynn itself, is included as one of the eight Kings Lynn study areas.

7.10 Kings Lynn is a medium sized town (population 41,000), medieval in origin, situated on the east bank of the tidal outfall channel of the Great Ouse. The town has a thriving harbour, including two enclosed commercial docks (the Alexandra and Bentinck Docks), tidal quays and an inshore fishing fleet. There are two extensive light industrial areas in the town, one in the docks area on the north side of the town and another, larger industrial area, including a gas-fired power station, on the south side of the town. Kings Lynn has expanded considerably during the past century, with major residential development to the north and east of the town in the North Lynn, South Wootton and Gaywood areas.

7.11 Kings Lynn has a long history of flooding from the tidal river. In 1981 the then Anglian Water Authority began work on a scheme to protect the town from tidal flooding from the Great Ouse. The scheme included 1,500m of concrete floodwall along the river frontage incorporating a total of 53 floodgates to permit access through the floodwall under normal conditions, the construction of four new outfall structures across tidal creeks and the replacement of the dock gates. The works, which were designed to give a 1 in 100 year standard of protection, were substantially complete by 1991. The earth embankments which form the Great Ouse tidal defences upstream and downstream of the town were also improved at this time.

7.12 Much of the town lies below the five metre contour line and the Environment Agency consider the great majority of Kings Lynn, including the whole of the town centre and the detached areas of South Lynn and West Lynn, to be within the tidal floodplain of the Great Ouse estuary. More recent development on higher land on the eastern edge of the town rises to an elevation of about 15mOD. The low-lying light industrial areas south of the A47 and west of the A10 are also within the fluvial floodplain of the River Nar.

7.13 The Great Ouse Flood Protection Scheme Relief Channel discharges to the tidal river through the Tail Sluice, 3km upstream of the town centre.

7.14 Three small but locally significant rivers - the River Nar, the Gaywood River and the Bawsey Drain - flow into the Great Ouse at Kings Lynn. The downstream ends of all three rivers run through the urban area and, although the tidal river presents the principal flood risk to the town, these three smaller rivers also constitute flood risk sources for substantial parts of the town.

7.15 The high-level Gaywood River and the low-level Bawsey Drain with which it shares a topographical catchment, are the responsibility of Kings Lynn Internal Drainage Board (as successor to the Gaywood IDB) as is the Pierpoint Drain in the Hardwick area to the south of the town and the North Lynn Drain. Both these watercourses are pump-drained; the former to the River Nar at South Lynn and the latter direct to the tidal estuary north of the dock area. As far as we are aware, no significant flood alleviation works have been undertaken on the Gaywood River or the Bawsey Drain since the hydraulic modelling of those watercourses was undertaken by the predecessors to Kings Lynn IDB in 2004.

7.16 Since the original SFRA report was issued, a scheme to reconfigure the Puny Drain system has been completed by the East of Ouse, Polver & Nar IDB (see Section 4). This scheme has resulted in an improved standard of flood protection in South Lynn and in the Nar Valley between Setchey Bridge and Kings Lynn (A47) bypass.

7.17 The town's surface water sewerage system includes a Sewer Relief Tunnel which has an outfall into the tidal channel of the Great Ouse in South Lynn, north of Portland Place. This tunnel, constructed during 1989/91, acts as an interceptor sewer (relief sewer) for twenty storm overflows from the town's combined sewerage system. The eastern arm of the relief sewer begins at Gaywood and follows the route of the Gaywood River as far as St John's Walk, where it meets the sewer's western arm which originates in Austin Fields. From St John's Walk the relief sewer runs south to Goodwins Road and then east to South Lynn. The diameter of the two arms of the Kings Lynn Sewer Relief Tunnel is 1,200mm, increasing to 1,650mm downstream of their confluence. The total capacity of the relief sewer is 1.7 cumecs, the capacity of Nar Lane Pumping Station near its outfall to the tidal river which comes into operation when the outfall is tidelocked.

SOUTH LYNN & LYNN SOUTH EXPANSION AREA (KL1)

General Description of the Study Area

7.18 South Lynn and the Lynn South Expansion Area are situated immediately south of Kings Lynn town centre, and the study area continues southwards to open land to the north of West Winch village. The study area is roughly rectangular in shape, extending over an area of 471 hectares of land between 2m and 6m OD. A plan of the Lynn South Expansion Area is given in Figure 7.1.

7.19 The western limit of the study area is the tidal channel of the Great Ouse and a 200m length of the Relief Channel just upstream of the Tail Sluice. Boat Street/Stonegate Street/Millfleet form the northern edge of the area between the Great Ouse and the A148. East of the A148 the northern boundary follows the A148 then the A149 to the Hardwick railway bridge. The study area's eastern boundary runs along the Kings Lynn – Cambridge railway line to the A47. At the A47 the eastern boundary runs eastwards along the A47 to the A10. Its southern boundary runs across open country just north of West Winch village.

7.20 The study area at present includes both 'greenfield' and 'brownfield' land and can be divided into two sections; one north and one south of the A47. To the south of the A47 and east of the River Nar the area is still entirely agricultural, consisting of largely arable land except in the north east where the Narrows Trading Estate is located. In the centre of the study area the strip of land between the Nar and Saddlebow Road is mostly arable farmland, but with a residential caravan site and grain storage depot on old railway land at the northern end. East of Saddlebow Road the land is mainly industrial or 'brownfield'. The site of the former Kings Lynn sugar beet factory, some of which is currently occupied by Council depots, occupies the land to the south of the A47 and a recently built gas-fired power station the SW corner of the study area. The Saddlebow Industrial Estate, which includes a stock-car racing stadium, occupies an area of land between Saddlebow Road and the old sugar factory site.

7.21 To the north of the A47, the study area can be considered in three sub-sections. Firstly South Lynn, situated in the angle between the Great Ouse and the Nar, is a largely residential area of terraced and estate housing with pockets of industrial and 'brownfield' land on the northern, eastern and southeastern edges of the area. Development of land between the River Nar and the old Harbour Branch railway line has recently commenced.

7.22 The sub-section east of the Nar and south of Hardwick Road (A149) includes a variety of 'brownfield' sites and waste land, allotment gardens, a cemetery, and a waste transfer site. The small Horsley's Fields Industrial Estate lies in the angle between the River Nar and Hardwick Road. The disused Harbour Branch railway runs diagonally across the southern end of the area. The third sub-section of the study area north of the River Nar is the heavily urbanised southern end of Kings Lynn town.

7.23 Natural ground levels across the study area vary between 2m and 6mOD, although the 'brownfield' scrub land along the western boundary of the area appears to have been raised above this level in places and the urban edge of Kings Lynn in the north of the area is also situated on slightly more elevated land. The open land to south of the study area is at the same general level whereas beyond the eastern edge of the area the land rises appreciably from the floodplain, reaching levels of between 7m and 9mOD along the A10 road.

7.24 The Environment Agency's Flood Map shows the great majority of the study area to be in Flood Zone 3, but with the built-up area of Kings Lynn between Mill Fleet and the Nar outfall in Zone 2. The study area's eastern margin at West Winch, the power station site, the raised land between the old sugar factory site and the A47 and small isolated 'islands' are in Zone 1.

7.25 The south east corner of the study area, to the east of Saddlebow Road and to the south of the A47, is within the fluvial floodplain of the River Nar for a 1 in 1000 year event. The properties along West Winch Road and the majority of the trading estate in the parcel of land between the A47 and West Winch Road are not in the Nar floodplain. The only other part of the study which is in a floodplain is the area of land to the north of the River Nar's tidal outfall in Kings Lynn. This piece of land is in the tidal floodplain of the Great Ouse.

7.26 The study area is divided between the East of Ouse, Polver & Nar Internal Drainage Board and the Kings Lynn Internal Drainage Board.

Hydrology of the Study Area

7.27 The tidal outfall channel of the Great Ouse, the Relief Channel and the River Nar must all be considered as principal flood risk sources for the Lynn South Expansion Area. There may also be a secondary flood risk from the Puny (Nar Valley) Drain, Gaywood River, Pierpoint Drain, and the King Lynn Sewer Relief Tunnel.

7.28 The tidal outfall channel of the Great Ouse runs along the western edge of the study area. The river is close to its estuary at this point and the flood risk is entirely tidal. The area's tidal flood defences consist of a substantial earth embankment from the 1987 River Nar Outfall sluice to the Tail Sluice. Between the Nar Outfall Sluice and Mill Fleet the defence line curves inland around Friars Fleet, once the tidal outfall channel of the Nar but now just a tidal creek. The earth embankment terminates at a point about 120m north of the Nar Outfall Sluice from where the pre-1987 concrete floodwall forms the defence line to Mill Fleet on the northern edge of the study area. Boal Street is ramped over the line of the floodwall adjacent to Mill Fleet and there are no floodgates in the section of floodwall south of Mill Fleet.

7.29 The Relief Channel discharges to the tidal river through the Tail Sluice which is situated close to the NW corner of the power station site. Significant flow in the Relief Channel only occurs under flood conditions when flood water is released to the tidal river through the sluice at low tide. At high tide the sluice prevents the backflow of tidal water into the Relief Channel.

7.30 The River Nar flows across the centre of the study area from north to south, discharging to the tidal river through its tidal sluice just south of Boal Quay at Friars Fleet. Prior to 1987 the River Nar's tidal outfall sluice was situated just downstream of the point where the Nar crosses over the Puny Drain but this sluice was made redundant by the new outfall sluice, sited much closer to the Great Ouse. Its channel has been canalised to a considerable extent and is substantially embanked throughout the study area. The Environment Agency has recently constructed a 600 metre flood diversion channel between the Nar and the Relief Channel at Saddlebow, upstream of the study area. When the water in the river reaches a critical level sluices in the river bank open automatically and flood water is diverted from the river to the Relief Channel. The scheme has been designed to give protection against flooding downstream to a 25-year return period standard.

7.31 The Puny Drain (sometimes also known as the Nar Valley Drain) runs parallel with the Nar, some 600 to 800m to the east of the river. The Puny Drain has recently been infilled from its tidal outfall into the Great Ouse back to the River Nar in South Lynn and the remainder of the northern end of the Drain has been regraded to flow southwards to a new outfall channel at Saddlebow (Clarke's Chase) where it is now pumped into the Relief Channel. This replaces the old gravity outfall to the tidal river at South Lynn.

7.32 Although upstream end of the Puny Drain is pumped to the Nar north of Wormegay, the length of the Drain west of the A10 at Setchey is effectively a separate pump-drained system. The relatively small catchment draining to the Puny Drain downstream of Setchey Bridge means that any flooding from this watercourse will still be confined to waterlogging or minor overtopping and thus limited in depth and extent.

7.33 Despite the recent reconfiguration of the Puny Drain system, the railway line still forms the watershed between the River Nar and the Puny Drain and, as far as we are aware, there are no siphons under the Nar in this area and the land west of the river will therefore still drain to the river. The SW corner of the study area is drained by the IDB's North Sea Bank Drain which has a gravity outfall to the Relief Channel 300m outside the area.

7.34 On the right bank of the River Nar, about 70m north of the Harbour Branch railway bridge, the Kings Lynn IDB's Pierpoint Pumping Station discharges the combined flows of the Pierpoint and Middleton Stop Drains to the river. There is a gravity outfall sluice from the IDB drainage system to the river adjacent to the pumping station. The Pierpoint Drain takes the surface water runoff from the eastern side of the study area.

7.35 The Gaywood River runs along the northern boundary of the study area at Millers Fleet. Between London Road and Church Street the Gaywood River flows in the 300m long Millfleet Culvert, at the upstream entrance of which there is an automatically raked weedscreen. The river's tidal outfall sluice is situated at the outer end of Mill Fleet at the junction of South Quay and Boal Street.

7.36 The downstream end of the Kings Lynn Sewer Relief Tunnel, some 1.7 km long, is routed through the northern half of the study area. Its 1,650mm diameter tidal outfall to the Great Ouse is equipped with a cast iron flap valve. Nar Lane Pumping Station is located in the study area, about 400m upstream of the tidal outfall.

7.37 Whilst in operation, the sugar factory had extensive silt settlement lagoons to the north and south. Apart from a small residual lagoon adjacent to the factory site, those to the north of the factory have long since been infilled and the land level raised. The cluster of smaller lagoons south of the factory has been infilled since the previous SFRA was completed.

Flood Risk within the Study Area

7.38 There are three principal sources of flood risk to this study area; one tidal, the Great Ouse, and two fluvial, the Relief Channel and the River Nar. The balance between probability and impact of flooding is, however, considerably different in each case.

7.39 The protection afforded to the study area by the tidal defence embankments along the east bank of the Great Ouse (the Tidal River) between the River Nar Outfall Sluice and the Tail Sluice is nominally the 1000-year return period (0.1% annual probability) event. This floodbank will not be subject to severe wave action and, moreover, the land immediately behind the embankment is the relatively raised land on the old sugar factory site. Hence this length of floodbank will not be subject to the same hydraulic stresses as other lengths of floodbank along the tidal river, and the annual probability of a failure at this location will therefore be less than 0.1%.

7.40 The most likely flood risk to the low-lying part of the study area east of Saddlebow Road is the River Nar, although the impact of fluvial flooding would be much less than that of tidal flooding from the Great Ouse. Even after the construction of the Nar diversion channel the annual probability of flooding of land along the Nar remains below 1.0% (the 1in100 year event). Although the Relief Channel does not abut directly on the study area, there is still a potential flood risk to the area from this source, though the flooding would probably reach the area via the River Nar. This risk is, however, considered to be significantly less than that from the Nar itself at this location.

7.41 For flood risk purposes the study area may be considered in two parts, north and south of the A47. To the north of the A47, the study area can be divided into three further sub-sections – South Lynn; E of the River Nar and S of Hardwick Road (A149); and to the north of the River Nar. South Lynn and the parcel of land between the River Nar and Hardwick Road are located in Flood Risk Category 1. The land surrounding Friars Fleet and the Friars Street School are located in Category 3 with the buildings to the south of Millfleet in Category 2.

7.42 To the south of the A47 the study area can be divided further to east and west of Saddlebow Road. The more elevated western part of the study area is generally too high to be in the fluvial High Risk category for flooding from the Nar and due to the height of the defences along the River Great Ouse, all of this land is located in Flood Risk Category 1. The principal flood risk to the lower, eastern part of the study area is fluvial and all of this part of the area will be in Category 2, apart from the higher land adjacent to West Winch Road and the Trading Estate of which is located in Category 1.

7.43 When taking into consideration the predicted impact of climate change the majority of the study area is either within the fluvial floodplain of the River Nar or the tidal floodplain of the River Great Ouse. Tidal Flood Risk Category 3 extends from the Great Ouse to the left bank of the Nar throughout the study area, except for the elevated land to the south of A47 directly adjacent to the Great Ouse. To the north of the River Nar outfall the Tidal Category 3 extends eastwards to Friar Street. The rest of the study area to the north of the Nar Outfall is located in Tidal Flood Risk Category 2.

7.44 Allowing for the predicted effects of climate change, Fluvial Flood Risk Category 3 extends eastwards from the right bank of the River Nar to the south of the A47. The elevated land adjacent to West Winch Road and the Trading Estate is still located in Category 1.

7.45 Due to the study areas close proximity to the tidal defences of the River Great Ouse the majority of the study area between the River Nar and north of the A47 is in the Hazard Zone as well as a small area in Saddlebow Industrial Estate and at Fishers Fleet.

Flood Risk to Downstream Areas

7.46 The study area drains largely to the River Nar and the Puny Drain. For the reasons given in para.7.33, the railway line is probably the boundary between the two catchments. A small part of the area drains to the Relief Channel via the North Sea Bank Drain. Any additional impermeable area runoff from the study area therefore has the potential to increase flood risk from these three watercourses.

7.47 The recent construction of the flood diversion channel from the Nar to the Relief Channel at Saddlebow has resulted in a considerable reduction in flood risk along the lower Nar, especially when the Nar is tidelocked by the Great Ouse. Although the diversion has been designed to cope with a 25-year return period flood event, it will continue to give flood alleviation benefit (albeit on a diminishing scale) for events of considerably higher return periods. The Nar should therefore at present be able to accept additional runoff from low return period events without jeopardising defence standards, although this will not apply to more extreme events, say of 20-years or higher return period. Additional impermeable area runoff from the Lynn South Expansion Area should therefore be routed through flood storage and flow attenuation devices.

7.48 Additional runoff from the study area to the Relief Channel will have an insignificant impact on flood risk in that channel, but any additional runoff from the area east of the railway should be routed through flood storage and flow attenuation devices before discharging to the North Sea Bank Drain, the Nar or the Puny Drain to ensure consistency throughout the study area.

WEST LYNN (KL2)

General Description of the Study Area

7.49 West Lynn is a large village on the west bank of the tidal outfall channel of the Great Ouse, directly opposite Kings Lynn with which it is linked by a pedestrian ferry. The West Lynn study area (222 hectares) includes not only the village itself but also an extensive area of agricultural land on the south, west and north of the village. A plan of the study area is given in Figure 7.2.

7.50 The irregularly shaped study area is bounded on the east by the bank of the tidal river and extends westwards, with local variations, as far as the Clenchwarton parish boundary. The area extends south as far as the modern A17 (Kings Lynn to Sutton Bridge) road. The northern boundary of the study area follows Ferry Road from the parish boundary to Bentinck Farm and then extends northwards for 400m to include a block of land north of Ferry Road.

7.51 Most of the village consists typically of residential development and associated facilities. There is, however, a large factory within the village envelope on a riverside site. There is also a large warehouse complex on the west side of Clenchwarton Road (the old A17) just south of the village, and another warehouse, service station and cafe at the intersection of the A17, A47 and Clenchwarton Road on the west of the river near Freebridge. The large undeveloped area surrounding the village is almost wholly arable farmland.

7.52 There is little variation in level across the West Lynn study area with ground levels ranging between 3m and 5mOD. The highest land, between 4m and 5mOD, is along St Peter's Road in the centre of the village which is of medieval origin. The fen farmland west of the village generally lies between 3m and 4mOD. Land levels continue to fall beyond the western boundary of the study area with considerable areas in and around Clenchwarton where ground levels in many areas are below 3mOD.

7.53 The West Lynn Drain, a large arterial drainage channel, flows from west to east through the study area to its gravity outfall to the Great Ouse in West Lynn village. The study area lies entirely within what was previously the West of Ouse Internal Drainage District, now administered by the Kings Lynn IDB.

7.54 The whole of the West Lynn study area is shown in Flood Risk Zone 3 on the Environment Agency's Flood Map, with two small 'islands' of Zone 1 in West Lynn itself on either side of West Lynn Drain.

Hydrology of the Study Area

7.55 The main hydrological feature of this study area is the tidal outfall channel of the River Great Ouse which, although it falls just outside the area, is the area's principal flood risk source. The earth embankment which forms the tidal river's west bank constitutes the primary tidal defence line on this side of the estuary. The Environment Agency maintains no secondary defence line in this area although the remains of the old medieval sea bank run along the western edge of the area. The line of a later, 17th Century, sea bank follows the West Lynn Drain from west to east through the study area to West Lynn, where it heads north along the lane known as Bank Side.

7.56 The West Lynn Drain, whose 20 sq.km. catchment includes the eastern side of Clenchwarton, Terrington St Clements and Tilney All Saints, has a gravity outfall to the tidal river at West Lynn. The West Lynn Drain catchment also includes almost all of study area KL2, apart from the small urbanised area west of Freebridge. This has its own separate tidal outfall to the river just downstream of Freebridge. The West Lynn Drain's original tidal outfall sluice at West Lynn is incorporated into the bridge where St Peter's Road crosses the Drain, but this sluice has now been supplemented by a newer sluice 150m downstream in a realigned section of the tidal embankment, constructed at the same time as the Kings Lynn Tidal Defence Scheme.

7.57 The land immediately to the north of the study area drains by gravity to the tidal river through Billy Kerkham Sluice, 3km north of West Lynn. The land outside the area to the south of the new A17 road lies in another separate small catchment which drains to the river through the Merries Farm outfall, 1.5km upstream of Freebridge.

7.58 There are IDB-maintained minor watercourses on either side of the West Lynn Drain within the study area. To the south, a drain runs from Clenchwarton Road to the West Lynn Drain along the western edge of the St Peter's Close housing estate. On the north side, a network of small drains serving the built-up area around Ferry Road and adjoining farmland discharges to the Drain at a point south of Sculthorpe Avenue.

7.59 There are no significant surface water sewers within the study area. However, the main Kings Lynn sewage treatment works is situated on the west bank of the Great Ouse 2km downstream of West Lynn. The town's main 600mm (24") foul sewer crosses the study area from south to north and runs in parallel with a similar 450mm (18") sewer from West Lynn. Both sewers are rising mains (i.e. the flow in them is pumped). There are two other smaller (250mm) pumped sewers which cross the study area.

Flood Risk within the Study Area

7.60 The primary flood risk to the West Lynn study area comes from the tidal estuary of the Great Ouse. The study area does not benefit from any secondary tidal defence line, although the primary defences were improved at the same time as the 1981/91 Kings Lynn scheme.

7.61 This scheme was designed to give a 100-year standard of protection against flooding but a recent assessment by the Environment Agency considered that the actual protection standard in this area was effectively 200 years, though the freeboard at this return period would be much diminished. However when comparing the crest level of the defences in West Lynn with the modelled water at this point, the standard of protection of the defences is greater than 1 in 1000 years and therefore the whole of the study area is just within Flood Risk Category 1, though the effect of climate change will be to increase flood risk in the study area to Category 3 by 2115, except for the centre of West Lynn where the flood risk with climate change will be Category 2.

7.62 Due to the study area's close proximity to the tidal defences of the River Great Ouse, some of the study area is located in the Hazard Zone. The whole of the study area to the north of Ferry Road, the agricultural land to the south of Bentinck Farm, the strip of land from the Discovery Centre to the A47 as far west as Clenchwarton Road, and properties near Church Close and Orchard Drove are all located within the Hazard Zone.

7.63 The West Lynn Drain is not considered to present a significant fluvial flood risk to the study area, provided that sufficient runoff attenuation is incorporated into the design of the drainage systems in future large scale urban developments upstream in the Terrington St Clement and Clenchwarton areas. The West of Ouse IDB consider that the West Lynn Drain system (Ref.9) gives a standard of protection throughout the study area considerably greater than 100 years, both now and in 2050, though upstream at Clenchwarton overtopping occurs at one location at 50 years, decreasing to 25 years by 2050 as a consequence of the predicted effects of climate change to that date.

Flood Risk to Downstream Areas

7.64 Any storm runoff from the study area will drain to the West Lynn Drain (or to the small outfall west of Freebridge) right at the downstream end of the catchment. As the West Lynn Drain discharges into the tidal estuary of the Great Ouse there can be no flood risk whatsoever to areas downstream.

7.65 Any runoff from the study area will be tidelocked in the West Lynn Drain during periods of high tide in the estuary. During heavy rainfall, the channel of the Drain will act as a flood storage reservoir for its entire catchment, with water levels building up in the Drain until tidelock conditions cease and discharge can again commence. An unusually large amount of freeboard is available in the West Lynn Drain at West Lynn. Unfortunately, land levels are up to a metre lower further upstream in Clenchwarton. If excess runoff is discharged to the Drain during tidelock conditions the effect will be felt in Clenchwarton well before it is felt in West Lynn.

7.66 Paradoxically, in this instance the unusual local topography means that runoff from the study area could increase flood risk upstream, and the local drainage authority can be expected to impose the same conditions on discharges from this study area, despite its proximity to the tidal river, than would be imposed elsewhere in the West Lynn Drain catchment. These conditions could include runoff attenuation devices and flood storage lagoons, or a financial contribution by the developers to general drainage improvements within the catchment. An alternative solution might be to provide an entirely separate surface water sewerage system for the two halves of the study area on either side of the West Lynn Drain, each with its own outfall to the tidal river.

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HISTORIC CORE (OLD LYNN) (KL3)

General Description of the Study Area

7.67 This study area, 169 hectares in extent, comprises the historic core and town centre of Kings Lynn. The western boundary of the area is the east bank of the tidal channel of the Great Ouse. The study area extends from Fisher Fleet in the north to Mill Fleet in the south. Its northern boundary runs SE from Fisher Fleet along the line of the Dock Branch railway as far as Gaywood Road (A148). The area's eastern boundary then runs from Gaywood Road (still along the line of the Dock Branch railway) to Tennyson Road (B1144) and then along the Kings Lynn – Cambridge railway line as far south as Hardwick Bridge. The southern boundary runs north east from Hardwick Bridge along Hardwick Road (A149) and London Road (A148) to Mill Fleet.

7.68 Apart from public open spaces, notably the public park at 'The Walks' and the cemetery to the south of the study area, the area is entirely built-up. The town's retail shopping area is centred on the High Street, between the Tuesday and Saturday market places. The eastern side of the area includes small pockets of older terraced housing, but the principal land use is commercial. The NW corner of the study area includes Alexandra Dock and the light industry and warehousing associated with it, and there is a small industrial estate at Austin Fields on the NE edge of the area. The study area also includes Kings Lynn railway station.

7.69 Inland from the tidal river, land levels rise gently from west to east, from just over 5mOD along the quayside to 6mOD in the Surrey Street / Norfolk Street and St James' Street areas. Almost all the land east of Railway Road / St James' Road (A148) is at or above 5mOD, with the highest point around the Surrey Street / Norfolk Street junction at just above 6mOD. West of this line and the town's slightly elevated core, land levels fall gently to 3mOD at St John's Walk.

7.70 The whole of the study area lies within what was previously the Gaywood Internal Drainage District. The Environment Agency's Flood Map shows the historic core of the town to be divided between Flood Zones 1 and 2, with an approximately 200m wide strip of Zone 2 land along the river frontage. The dock area in the north of the study area and the southern and western parts of the study area are all in Zone 3. A plan of the study area and the surrounding land is given in Figure 7.3.

Hydrology of the Study Area

7.71 The principal hydrological feature of the study area is the tidal outfall channel of the River Great Ouse which forms the western boundary of the area. The Gaywood River should also be considered as a primary flood risk source, although of far less significance than the tidal river. There are two much smaller, secondary flood risk sources within the study area, the Bawsey Drain and the Kings Lynn Sewer Relief Tunnel.

7.72 The Great Ouse tidal flood defences within the study area consist of a series of flood walls and interlinked buildings along the river frontage between Fisher Fleet and Mill Fleet. In places the defence line is along the river's edge, in others (e.g. South Quay) it runs along the landward edge of the quayside. At Fisher Fleet and Purfleet the defence line runs round the perimeter of the tidal inlet. In order to maintain public and private vehicular and pedestrian access across the defence line a total of 53 floodgates have been inserted into the floodwalls or across doorways etc, all of which have to be fully closed in advance of a tidal flood event to ensure the integrity of the town's flood defences.

7.73 The Gaywood River rises on Massingham Heath, about 16km east of Kings Lynn. The river is a typical chalk stream, fed by springs in the Grimston / Gaywood area. Chalk streams are characterised by high baseflows and modest but prolonged flood peaks. The Gaywood River enters the study area at Kettlewell Lane, flows south through the Highgate area of the town, and is culverted beneath the railway station. It re-emerges downstream of the station to flow south through St James' Park, where it has a parallel, backwater channel, the Walks Rivulet. At Broad Walk the river turns to flow west for the final 800m to the tidal river. Between London Road and Church Street the Gaywood River flows in the 300m long Millfleet Culvert, at the upstream entrance of which there is an automatically raked weedscreen. The river's tidal outfall sluice is situated at the outer end of Mill Fleet at the junction of South Quay and Boal Street.

7.74 The St John's Walk recreation ground, on the left (east) bank of the Gaywood River has been enclosed by earth embankments on the north, east and south sides to create an informal and uncontrolled flood storage area adjacent to the river. Flood water to a depth of 300mm has been recorded in this storage area.

7.75 The Bawsey Drain, a low-level watercourse draining low land on either side of the Gaywood River in the broad valley between Reffley Wood and the Queen Elizabeth Hospital, crosses the northern corner of the study area in a culvert 40m south of Alexandra Dock. Although the Bawsey Drain is a Kings Lynn IDB watercourse this culvert is understood to be the responsibility of the Kings Lynn Dock authority. The Drain's tidal outfall sluice is at the downstream end of the culvert, 100m south of the Alexandra Dock entrance lock.

7.76 During heavy rainfall, surface water runoff from the eastern side of the study area enters the western arm of the Kings Lynn Sewer Relief Tunnel by means of storm overflows from the town's combined sewer system. The relief sewer's western arm begins on the northern boundary of the area at Austin Fields, runs south under Blackfriars Road before heading east along St John's Walk to connect with the Relief Sewer's eastern arm just west of the B1144 road from where the relief sewer flows south through the South Lynn study area (KL1) and its outfall to the tidal river in South Lynn.

Flood Risk within the Study Area

7.77 The crest level of the floodwalls along the right (east) bank of the Great Ouse through the town centre indicates a standard of protection approximating to the 200-year event. Nevertheless, the presence of so many floodgates in the defences, all of which have to be closed before the arrival of the peak of a surge tide, introduces a considerable element of residual risk. The exceptional and unquantifiably random nature of this risk is such as to bring the whole of the study area within Tidal Flood Risk Category 2, except for a large elevated area between Austin Street and St James Street which is in Category 1.

7.78 It should, however, be emphasised that the resultant flooding would be limited in both duration and volume. Its impact, except in the immediate proximity of an open floodgate, would be relatively minor and limited to shallow sheets of fast flowing floodwater along roads and streets, quite probably confined within kerb height. This water would flow eastwards overland until it reached the Gaywood River, where it would be intercepted and distributed upstream and downstream along the river channel. There could be some ponding of the floodwater in low-lying land on the eastern edge of the study area.

7.79 The results of the hydrological / hydraulic modelling of the Gaywood River system (Ref.10) suggest that there is no risk of fluvial flooding in any part of the Historic Core study area for flood events of return periods less than 100 years (1% annual probability). Hence the principal flood risk, even for land along the Gaywood River, remains tidal as regards the dominant flood risk category.

7.80 Due to the predicted effects of climate change those parts of the study area which were in Flood Risk Category 2 are likely to move to Category 3, and the land within Flood Risk Category 1 will move to Category 2, except for the Highgate district of the study area which will remain in Category 1 even allowing for the impacts of climate change.

7.81 Only the fringes of the study area along the right bank of the River Great Ouse and around Fishers Fleet are located within the Hazard zone, due the topography of those areas.

Flood Risk to Downstream Areas

7.82 Since the study area is immediately adjacent to the tidal outfall channel of the River Great Ouse, and as the surface water runoff from the whole area drains to the Great Ouse, or to minor watercourses or sewers which drain to the tidal river, there are no 'downstream areas' which could be at increased risk of flooding as a result of urban development in the study area, apart from the those along the Relief Sewer. In any case, as any future development in the area will inevitably be redevelopment, the question of increased runoff from newly impermeable surfaces does not arise.

7.83 The north east section of the South Lynn study area (KL1) could, in theory, be at increased risk of localised flooding from increased storm overflow discharges to the Kings Lynn Sewer Relief Tunnel through which it flows but any such discharges, even if they did arise, would be limited by the finite capacity of the underground overspill structures discharging to the relief sewer. Anglian Water consider that, because of its depth, flooding from the Sewer Relief Tunnel itself is very unlikely. This increased risk can therefore be disregarded.

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NORTH LYNN (KL4)

General Description of the Study Area

7.84 The North Lynn study area is situated on the northern edge of the Kings Lynn urban area. The 131 hectare area has the shape of an inverted, truncated cone. The western edge of the study area follows the east bank of the Great Ouse from Fisher Fleet to the North Lynn Drain outfall. Its eastern edge follows the A1078 road (Edward Benefer Way) from the Dock entrance gates north to North Lynn Drain, which forms the study area's northern boundary.

7.85 Apart from the land to the north of North Lynn Farm, the whole of the study area consists of existing industrial developments. The SE part of the study area is occupied by Bentinck Dock and associated quaysides and warehousing. On the west side of the study area the Riverside Industrial Estate includes a number of substantial industrial installations. On the east side of the area there is an oil storage depot on the north side of Estuary Road. Together with the fire station, there is also a primary school and residential street (Jeffrey Close) in the NE corner of the area.

7.86 Land levels in the area vary from just above 2mOD along Kilhams Way and Estuary Road in the NE corner, to around 5.5mOD in the dock area, though this area was presumably raised to this level during the excavation of Bentinck Dock. The land around North Lynn Farm is marginally higher than the rest of the natural ground surface in the area, at nearly 5mOD. Precise land levels in the Riverside Industrial Estate are not known but are all below 5mOD. There is a slight but general fall in levels across the area from SW to NE.

7.87 The whole of the North Lynn study area is shown as Flood Zone 3 on the Environment Agency's Flood Map, with the exception of the an area of Zone 1 in the SW corner of the Riverside Industrial Estate and an area of Zone 2 between the Industrial Estate and Bentinck Dock. The study area is also entirely within what was previously the Gaywood Internal Drainage District. A plan of the study area is given in Figure 7.4.

Hydrology of the Study Area

7.88 The North Lynn study area lies mainly within the North Lynn Drain catchment. It is likely that some of the paved areas around Bentinck Dock drain direct to the dock, and thence to the tidal river via Alexandra Dock, but relative ground levels indicate that the majority of the area must drain northwards to the North Lynn Drain. This assumption is reinforced by the network of small IDB drains and riparian watercourses north of Estuary Road.

7.89 Flows in the North Lynn Drain are pumped to the tidal outfall channel of the Great Ouse at the Kings Lynn IDB's North Lynn Pumping Station which is situated at the NW corner of the study area. This modern electric pumping station has been designed to accommodate the additional surface water runoff generated by existing development in the study area as well as from residential areas of North Lynn and future development within the adjacent Wootton Marshes. The pumping station incorporates space for the future installation of an extra pump. The IDB have assumed that additional runoff will not be attenuated at source but will be catered for by pump capacity and storage volume within the Board's drains, enlarged where necessary.

7.90 Although the Bawsey Drain runs parallel with the eastern boundary of the study area and only 100m from it, the Drain is separated from the study area by the remains of the Old East Sea Bank and Edward Benefer Way (A1078). The old sea bank no longer fulfils any practical function but would in historical times have formed the northern limit of the Bawsey Drain catchment. It is therefore unlikely that this watercourse plays any significant part in the drainage of the North Lynn study area.

7.91 There is a large sewage pumping station on the east bank of the Great Ouse west of North Lynn Farm. This deals with the foul sewage from the northern part of the town which reaches the pumping station in a 600mm x 900mm gravity sewer and three smaller pumped sewers, all of which are routed from east to west across the study area. The larger, gravity main sewer almost certainly carries some surface water and therefore presents a residual risk of localised flooding along its route within the study area. There are no Anglian Water surface water sewers in this study area.

Flood Risk within the Study Area

7.92 The principal flood risk source for the North Lynn study area is the tidal outfall channel of the Great Ouse. Ground levels in the area are substantially lower than the 200-year return period surge tide level in the river and the area is protected by the river's east bank tidal defences. There is a concrete floodwall round Fisher Fleet with floodgates through it for access to the quayside, which is used by local inshore fishing boats. This short length of floodwall has a crest level of 6.3mOD, 0.2m above the 200-year flood level. Fisher Fleet is not subject to any significant wave action. The floodwall is less than 1m high and there are only seven floodgates along the study area's tidal river frontage.

7.93 North of Fisher Fleet the river's tidal defences are formed by an earth embankment. Although this is, technically, a 'soft' defence there is a tarmac access road to the rear of the Riverside Industrial Estate along the embankment's outer berm and this, together with the exceptional overall width of the bank, suggests that the risk of breaching is very unlikely. Crest levels along this bank are of the order of 7.0mOD and therefore well above the 200-year return period tide level.

7.94 The flood risk to the study area from the unembanked North Lynn Drain is also very small. The North Lynn Drain has recently been modelled in conjunction with the Gaywood River study (Ref.10), although the North Lynn and Gaywood River / Bawsey Drain catchments are independent of each other. The present performance of the North Lynn Drain was modelled for the 100-year return period event and the results showed that the system has sufficient capacity within its drainage channels to contain the 100-year flood event, even without the aid of pumping.

7.95 Although the defence standard will gradually diminish if the Wootton Marshes (north of the study area) are developed, the North Lynn Pumping Station should ensure that the defence standard remains well in excess of 100-years. Serious mechanical or electrical failure at the pumping station could in future give rise to a residual flood risk within the study area (and Wootton Marshes) but this would be limited to the low-lying area north of Estuary Road and west of Kilhams Way. As such flooding would also occur over a wide area of the Wootton Marshes its impact would be confined to waterlogging, even on the low-lying land in the study area.

7.96 As there are no major surface water sewers in the study area, there is no significant flood risk from this source. Although the presence of the trunk foul sewer across the area poses a residual flood risk, the impact of any flooding from this source would be fairly localised.

7.97 Taking into account the various factors discussed above, the flood risk for the eastern half of the study area is Tidal Flood Risk Category 2 and the western half of the study area is in Category 1. A straight line running NE from Fisher Fleet to the west of the Bentinck Dock timber yard and to the west of North Lynn Farm forms the boundary between the two flood risk categories. The predicted effects of climate change could eventually bring the study area into Flood Risk Category 3 within one hundred years. The fluvial flood risk in this study area is also Category 2, but the impact of fluvial flooding from the small North Lynn catchment would be substantially less than that from tidal flooding. The majority of the study area, except for Bentinck Dock, is also located within the Hazard zone.

Flood Risk to Downstream Areas

7.98 Redevelopment of what is already a largely impermeable study area will not result in any substantial increase in surface water runoff.

7.99 Although some of the southern and western fringes of the study area may drain to the Great Ouse, Fisher Fleet or Bentinck Dock, most of the area will continue to drain towards the North Lynn Drain. This is a pump-drained watercourse and the pumping station at the tidal outfall will have a finite capacity. This has, however, been designed with sufficient capacity to cope with the additional runoff from this study area and runoff generated from newly impermeable surfaces in the study area should not therefore require specific attenuation measures.

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GAYWOOD (KL5)

General Description of the Study Area

7.100 The Gaywood study area is situated on the north eastern side of the Kings Lynn urban area. It a roughly rectangular area of land extending over 751 hectares between Edward Benefer Way (A1078) and the Kings Lynn eastern bypass (A149). Edward Benefer Way and the bypass form the study area's western and eastern boundaries respectively, with Gayton Road (A1076), Lynn Road (A148) and the Dock Branch railway forming its southern boundary. The study area's northern boundary follows Low Road (A1078) and Grimston Road (A148). A plan of the study area is shown in Figure 7.5.

7.101 A large proportion of the land in the eastern half of the study area and some in the centre of the western half of the study area is currently undeveloped, consisting of a mixture of arable farmland, abandoned farmland, public open spaces and playing fields. Much of this 'greenfield' land lies along the broad, flat valley of the Gaywood River but it also includes Reffley Wood and the slopes of Knights Hill. The rest of the study area is residential, interspersed with public open spaces.

7.102 Within the study area ground levels vary from 3mOD in the Gaywood River floodplain, rising to 51mOD at the summit of Knights Hill in the NE corner of the study area and to about 13mOD in the developed urban area along Gayton Road on the area's southern boundary. Ground levels in the Gaywood River floodplain appear to be generally around 4mOD but with local levels down to 3.0mOD at the north end of Edinburgh Avenue and the west end of Salters Road. To the west of Wootton Road (A148) land levels are generally around 4mOD.

7.103 The large majority of the western half of the Gaywood study area, west of Wootton Road, is shown on the Environment Agency's Flood Map to be in Flood Zone 3, with an area of Zone 1 in the angle between Wotton Road and Low Road and isolated islands elsewhere. By contrast, most of the eastern half of the study area is in Flood Zone 1, with only the Gaywood River floodplain running through the centre of the area in Zone 3. Much of the western half of the study area and the central strip through the eastern half is in the erstwhile Gaywood IDB area.

Hydrology of the Study Area

7.104 The study area is situated in the Gaywood River catchment. The Gaywood River is a high-level watercourse and within the study area is supplemented by the low-level Bawsey Drain system. Although serving the same topographical catchment, each watercourse has its own tidal outfall to the Great Ouse, some 900m apart. The Bawsey Drain and its tributary, the Black Drain, drain the low-lying land on either side of the Gaywood River between the Wootton Road (A148) and Grimston Warren. Black Drain is culverted under Gaywood River 150m upstream of the A148 and joins the Bawsey Drain 80m upstream of the A148. Bawsey Drain, which serves the area south of the Gaywood River, is then culverted under Gaywood River 100m downstream of the A148. It is understood that under flood conditions water can overspill from the Gaywood River into Bawsey Drain at this point.

7.105 In recent years Bawsey Drain has been divided on the line of Spring Lane at the upstream limit of the IDB-maintained watercourse. The severed, upstream end of Bawsey Drain is now pump-drained to the Gaywood River by a small private pumping station at OS Grid Ref. TF653212. Supplementary information has been received from the Consulting Engineers who undertook the Gaywood River Strategic Review (Ref.10) that under flood conditions flow from east to west can occur across and beneath Spring Lane.

7.106 There are two small flood storage reservoirs (FSRs) in this study area, both associated with recent residential development within the area. On the northern edge of the area the Reffley FSR receives surface water runoff from the Seathwaite Road area and on the opposite side of the Gaywood River valley the Elvington FSR serves the Spring Wood area. Both FSRs discharge to the Bawsey Drain system.

7.107 The eastern arm of the Kings Lynn Sewer Relief Tunnel serves the urban areas along the western edge of the Gaywood study area. The sewer relief tunnel conveys overspill from the combined sewer systems in the older parts of the town, including a number of overflows in the study area, to an outfall to the tidal river in South Lynn. This tunnel was constructed to alleviate localised sewer flooding in certain parts of the town during storm rainfall though localised flooding is still possible due to limited capacity in the sewer systems overflowing to the relief sewer.

Flood Risk within the Study Area

7.108 Almost the whole of the western half of the Gaywood study area is theoretically at risk of tidal flooding from the Great Ouse, since nearly all of the land there is below the 200-year peak tide level. In practice, any flood water would have to traverse the densely built up areas of the town in Study Areas 3 and 4 before it reached the Gaywood study area. Furthermore, since breaching of Kings Lynn town's tidal floodwalls is very unlikely (though the risk of inflow through open floodgates remains) the volume of tidal flood water flowing east through the town will be limited - see paras. 7.78 and 7.79.

7.109 The low railway embankment on the disused Hunstanton line would also tend to act as a barrier to the passage of flood waters, as would the Wootton Road (A148) across the narrowest part of the Gaywood River valley. Bawsey Drain and Gaywood River would all tend to intercept tidal flood flows within the town and these would be conveyed upstream along these watercourses, although the reverse flow would be throttled by bridges, culverts etc. However, since the volume of water finding its way into the channels of these two watercourses during the short duration of the tidal flood peak would be relatively limited (flood water would start to flow back into the Great Ouse as soon as the peak had passed) it is quite possible that the flood water in these watercourses would not even overtop their banks within the study area. Even if overtopping did occur, the resultant flooding could well be confined to the lowest land alongside the watercourses.

7.110 The effective inland limit of tidal flooding has therefore been taken as the Old East Sea Bank along Bawsey Drain and to the west of Sir Lewis Street. The fluvial flood limit extends east of Columbia Way through the allotment gardens to Wootton Road (A148) and then extends from Wootton Road to the Kings Lynn Eastern Bypass (A149).

7.111 The modelling of the Gaywood River / Bawsey Drain system (Ref.10) showed quite dramatically how the low-lying land along the Gaywood River valley between Wootton Road and the Eastern Bypass (A149) acts as a de-facto flood storage reservoir for the Gaywood River, thereby effectively reducing the risk of fluvial flooding in the urban area through which the river flows to at least a 100-year return period standard, i.e. Flood Risk Category 2. Hence the Gaywood River floodplain upstream of Wootton Road can be regarded as a functional floodplain with a correspondingly high flood risk, and is therefore within Flood Risk Category 3b.

7.112 The relatively recent construction of the Kings Lynn Sewer Relief Tunnel suggests that the risk of serious surface water sewer or combined sewer flooding at the western end of the study area can be disregarded in the short and medium term future.

7.113 Allowing for the predicted effects of climate change in the next hundred years, the extent of fluvial Flood Risk Category 3 should not be significantly different from the present day situation. However, the tidal Flood Risk Category 3 envelope would extend from the western edge of the study area as far east as Columbia Way and to the eastern limit of the North Lynn Industrial Estate.

7.114 Only the playing field immediately to the east of Edward Benefer Way is located within the tidal Hazard Zone.

Flood Risk to Downstream Areas

7.115 The heavily urbanised areas of Kings Lynn town centre and South Lynn are situated downstream of the Gaywood study area. The Gaywood / Bawsey system relies wholly on gravity drainage and its outfalls are 'tidelocked' during periods of high tide in the Great Ouse. If any further development were to take place in this catchment all storm runoff from that development would have to be fully attenuated to avoid increasing flood risk in the downstream urban areas. The provision of effective and reliable runoff attenuation on flat, low-lying land is not always easy to achieve as any flood storage areas might have to be routinely pumped to ensure that the full storage volume was always available when required.

7.116 These concerns are, however, eclipsed by the findings of the Gaywood River Strategy review. Although the Kings Lynn IDB's proposed Gaywood Link Scheme will enable the flood overspill from Gaywood River to the Bawsey Drain to be controlled, the IDB has concerns about the hydraulic capacity of the Gaywood / Bawsey system and would strongly oppose any development of 'greenfield' land in the Gaywood River floodplain east of Wootton Road which would seriously reduce the capacity and hence the effectiveness of the existing de-facto flood storage reservoir in the floodplain upstream of the A148, thereby seriously increasing flood risk downstream. The problem is one of ‘displaced water’ and would not in any way be alleviated by the attenuation of runoff from development in this area.

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HARDWICK (KL6)

General Description of the Study Area

7.117 The Hardwick study area extends over 402 hectares of land on the eastern and southeastern edges of the Kings Lynn urban area. The compact but irregularly shaped area is bounded by Queen Elizabeth Way (A149, the Kings Lynn eastern bypass) to the east, Gayton Road (A1076) to the north and the Kings Lynn southern bypass (A47) to the south. The study area's western boundary follows the Kings Lynn to Ely railway line northward from the A47 until Kings Lynn railway station, after which the boundary continues northwards along the line of the Dock Branch railway to Gaywood Road.

7.118 The study area is divided into two by the branch railway to Middleton quarry which extends through the centre of the area. The northern half of the study area is mainly residential - Fairstead and the southern part of Gaywood - but also includes three schools and a college. Along the northern side of the railway line there are open grasslands and a wooded area. Many of the grassed areas are the schools' playing fields.

7.119 The southern half of the study area is occupied by the existing Hardwick Industrial Estate which includes food processing and canning factories, a glassworks, miscellaneous light industry and motor vehicle dealers. There is a small residential area (Kings Avenue / Extons Place) in the north west section of this area. The eastern end of the area on either side of the Middleton Stop Drain is still farmland, both arable and fallow. There are small pockets of waste land in the north west and south west corners of the area, the former being a mixture of wetland and woodland. Hardwick Road (A149), one of the main roads into the town, passes through this southern section of the study area.

7.120 The southern half of the study area is relatively level and low-lying, and ground levels within the area vary between 2m and 5mOD. The lowest land in the southern half of the area is within Hardwick Industrial Estate with the highest land in the vicinity of the Hardwick roundabout on the southern edge of the area where the land rises locally to above the 5m contour. In the northern half of the study area the land rises northwards from the railway line to a level of 14mOD on the Gayton Road ridge.

7.121 A large part of the Hardwick study area is shown on the Environment Agency's Flood Map as being within Flood Zone 3. North of the quarry branch railway the flood zone extends across the western edge of the residential area as far as Bagge Road and Parkway. Almost all of the southern half of the study area is shown to fall within Flood Zone 3 with the exception of the eastern corner of Hardwick Industrial Estate north of Hardwick roundabout and another small area in the angle between the branch railway and the eastern bypass east of the Industrial Estate. The study area is divided between two IDB areas; the Kings Lynn IDB north of Hardwick Road and the East of Ouse, Polver & Nar IDB south of Hardwick Road. A plan of the study area is presented in Figure 7.6.

Hydrology of the Study Area

7.122 Although the tidal and fluvial floodplains are not differentiated on the Agency's Flood Map, the tidal outfall channel of the Great Ouse must be considered as the area's principal flood risk source. The area's other main flood risk sources include the River Nar, the Puny Drain, and the Pierpoint Drain / Middleton Stop Drain system.

7.123 The east bank of the tidal channel of the Great Ouse is nowhere nearer than one kilometre from the western edge of the study area and, south of Friars Fleet, is separated from the study area by the South Lynn urban area and the embanked channel of the River Nar. North of Friars Fleet the study area is separated from the tidal river by the densely built-up urban area south of Kings Lynn town centre.

7.124 The River Nar comes to within 200m of the SW corner of the study area. This reach of the Nar is, however, downstream of the Saddlebow flood diversion channel by which flood flows in the river are diverted into the Relief Channel. The Puny Drain, which drains all of the study area south of Hardwick Road, flows beneath the Kings Lynn – Ely railway line and A47 road at the SW corner of the area, heading south towards its new pumped outfall on the east bank of the Relief Channel in Saddlebow. Unlike the Nar, the Puny Drain is not an embanked watercourse.

7.125 The Middleton Stop Drain and its smaller tributary, the Pierpoint Drain, both flow from east to west across the study area on roughly parallel courses some 150m to 500m apart. The combined catchment of the two drains extends as far east as Gayton and Massingham Heath. Downstream (west) of Gayton the valley floor is flat and the principal watercourses are all IDB maintained. One kilometre upstream of the Kings Lynn eastern bypass (A149) a small land drainage pumping station had to be installed by the then Gaywood IDB to drain an area of low-lying farmland in the valley north west of Fair Green.

7.126 The Middleton Stop Drain originally had a gravity outfall into what was then the tidal outfall channel of the River Nar. When the Kings Lynn flood defence scheme was built in the early 1980s, the Nar outfall sluice was rebuilt much closer to the Great Ouse, downstream of the Middleton Stop Drain outfall sluice. As a result, the Middleton Stop Drain tidal outfall was sealed and the drain was diverted into the Pierpoint Drain on the eastern edge of Kings Lynn cemetery, 200m outside the study area. The combined drains are now pumped into the River Nar at Pierpoint Pumping Station, about 450m north of the site of the old River Nar outfall sluice. The whole of the study area north of Hardwick Road is drained by the Middleton Stop Drain / Pierpoint Drain system.

7.127 Within the study area there is also a flood storage reservoir, Swallowfield FSR, to the north of the Middleton quarry branch railway line. This reservoir discharges to a tributary drain in the Middleton Stop Drain system alongside the railway.

Flood Risk within the Study Area

7.128 As much of the land in this study area is also below the 200-year peak tide level, the most serious potential flood risk in this study area is tidal flooding from the Great Ouse. Although the western boundary of the study area is as close to the tidal defence line as that Gaywood study area, any flood water would again have to cross a heavily built up area before it reached the study area and, here too, the low railway embankment along the western boundary of the area would act as an effective barrier to the eastward passage of flood water. It is therefore very unlikely that overtopping of the Kings Lynn tidal defences in a 200-year event would cause flooding in the study area.

7.129 The Middleton Stop Drain and Pierpoint Drain would both tend to intercept tidal flood flows and these would be conveyed upstream along their channels, although the reverse flow would be throttled by bridges and culverts. Here too, the volume of water finding its way into these two watercourses during the short tidal flood peak would be relatively limited, especially as much of the tidal flood water would be intercepted by the River Nar before it reached the two IDB Drains. It is therefore very possible that the tidal flood water in these watercourses would not even overtop their banks and, even if overtopping did occur, the resultant flooding could well be confined to the lowest land alongside the watercourses.

7.130 The risk of overtopping and fluvial flooding from the Pierpoint and Middleton Stop Drains is determined by the pump capacity at Pierpoint Pumping Station. (There is, of course, a residual risk associated with plant failure at the pumping station.) At the time of the original SFRA the then Gaywood IDB estimated that the standard of service provided by this pumping station was a flood event with a return period of between 50 and 75 years. Recent improvements to Pierpoint pumping station have increased this standard to nearer 100 years, although hydraulic modelling results (Ref.10) indicate marginal flooding within the catchment.

7.131 From the foregoing, it can be deduced that the great majority of the Hardwick study area is within Flood Risk Category 1. Hardwick Industrial Estate to the east of the railway and to the north of Kings Lynn southern bypass is the only part of the study area to be located in fluvial Flood Risk Category 3.

7.132 Taking into the consideration the predicted effects of climate change to the year 2115, the extent of fluvial Flood Risk Category 3 will be much the same, but Hardwick Industrial Estate and the north west corner of the study area in the vicinity of Gaywood Park High School would become within tidal Flood Risk Category 2.

Flood Risk to Downstream Areas

7.133 Since the majority of the area is already developed, the volume of additional runoff likely to be generated by further development is relatively small, and will be almost wholly derived from the undeveloped land along the eastern edge of the study area which drains to the Middleton Stop Drain or Pierpoint Drain. Any resultant increase in flood risk in the Middleton Stop Drain / Pierpoint Drain system will be correspondingly small. Nevertheless the Kings Lynn IDB is concerned about the potentially serious impact of flooding in the heavily urbanised downstream end of the catchment. They are therefore likely to oppose any development on the 'greenfield' land on the eastern edge of the study area without appropriate measures being taken to improve the existing standard of protection in the area.

7.134 The land west of the study area, between the railway line and the River Nar, is generally a metre higher than land in the Hardwick Industrial Estate east of the railway. Any increased flood risk caused by additional runoff from within the study area will therefore be experienced almost entirely within the study area itself, or on agricultural land upstream of the area, south east of Queen Elizabeth Way.

7.135 The volume of additional runoff likely to be generated by the development of the small area of waste land in the SW corner of the study area and discharged to the Puny Drain is minimal. If adequately attenuated, it should have no appreciable effect on flood risk on the land adjacent to the Puny Drain, either upstream or downstream of the Kings Lynn southern bypass (A47).

7.136 Although the increased fluvial flood risk is marginal, the surface water runoff from any further development within the study area should, nevertheless, be routed through flow attenuation devices and/or flood storage lagoons to avoid increasing flood risk in downstream urban areas. This should apply as much to development south of Hardwick Road as to development on ‘greenfield’ land east of the existing Hardwick Industrial Estate (para.7.133) to ensure a consistent application of development control policies. As has been pointed out previously, the provision of effective and reliable runoff attenuation on flat, low-lying land is not always easy to achieve as any flood storage areas may have to be routinely pumped to ensure that the full storage volume was always available when required.

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EASTERN EXPANSION AREA (KL7)

General Description of the Study Area

7.137 The Kings Lynn Eastern Expansion Area covers 231 hectares and is located 2.5km south east of the town centre. The Eastern Expansion Area and its study area is entirely outside the area covered by the potential development areas considered in the original SFRA.

7.138 The Eastern Expansion Area study area is roughly rectangular in shape. Its western boundary follows West Winch Road (A10) from Mill Lane northwards to the A47 at Hardwick roundabout. Queen Elizabeth Way (A149) forms the area's northwestern boundary as far as the Middleton quarry branch railway. The study area's northern boundary follows the branch railway line for 600m to the line of a dismantled railway. The area's western boundary follows the line of the disused railway for 500m and then a series of smaller drains and ditches to the A47 on Constitution Hill. The study area's southern boundary is a straight line from the A10 at Mill Lane, West Winch eastwards to the A47 on Constitution Hill. A plan of the study area is shown in Figure 7.7.

7.139 The study area is almost entirely undeveloped 'greenfield' land, apart from miscellaneous residnetial properties along the east side of the A10 road between Mill Lane and Hardwick roundabout. The great majority of the study area consists of mixed farmland, both arable and pasture. The large roundabout at the A10/A47 junction is included in the western edge of the study area. The lower land in the study area falls within what was the Gaywood Internal Drainage District, now part of the Kings Lynn IDD.

7.140 The study area falls in elevation from 17mOD at Mill Lane Farm to 3mOD along the Pierpoint Drain. The land also falls gently towards West Winch Road from Mill Lane Farm. Ground levels are much more uniform to the north of Pierpoint Drain, between 3m and 5mOD, as most of this area is in the floodplain of the Pierpoint and Middleton Stop Drains. The highest point in the study area is at 22mOD at the SE corner, on Constitution Hill.

7.141 The Environment Agency's Flood Map shows the whole of the study area north and west of Pierpoint Drain to be in Flood Zone 3 in the absence of any defences. Although the Flood Map does not distinguish between tidal and fluvial flood risk, the flood risk east of the Kings Lynn eastern bypass is assumed to be entirely fluvial.

Hydrology of the Study Area

7.142 The Middleton Stop Drain and its smaller tributary, the Pierpoint Drain, both flow from southeast to northwest across the northern part of the study area on roughly parallel courses some 300m to 600m apart. The combined catchment of the two drains extends as far east as Gayton and Massingham Heath. Downstream (west) of Gayton the valley floor is flat and the principal watercourses are all IDB maintained. One kilometre upstream of the Kings Lynn eastern bypass (A149) a small land drainage pumping station had to be installed by the then Gaywood IDB to drain an area of low-lying farmland in the valley north west of Fair Green.

7.143 The Middleton Stop Drain originally had a gravity outfall into what was then the tidal outfall channel of the River Nar. When the Kings Lynn flood defence scheme was built in the early 1980s, the Nar outfall sluice was rebuilt much closer to the Great Ouse, downstream of the Middleton Stop Drain outfall sluice. As a result, the Middleton Stop Drain tidal outfall was sealed and the drain was diverted into the Pierpoint Drain on the eastern edge of Kings Lynn cemetery. The combined drains are now pumped into the River Nar at Pierpoint Pumping Station, about 450m north of the site of the old River Nar outfall sluice.

7.144 There are a number of small ditches in the southwestern part of the study area which drain the land on the west side of Constitution Hill. This land drains across West Winch Road and into Puny Drain and thence to that Drain's new pumped outfall to the Relief Channel at Saddlebow. There are no surface water sewerage systems within the study area.

Flood Risk within the Study Area

7.145 The principal source of flood risk to the study area will be fluvial flooding from the Pierpoint and Middleton Stop Drains. Due to the topography of the study area, notably the presence of Constitution Hill, only the larger, northern part of the study area is potentially at risk from these Drains.

7.146 The Strategic Flood Risk Map (Figure 5.1) shows the whole of the study area to the north and east of Hardwick roundabout to be in fluvial Flood Risk Category 3, apart from Hardwick Farm itself and a small area of land in the northern corner of the study area. The remaining parts of the study area are all located In Flood Risk Category 1 due to the elevated nature of the land. No part of the study area is at significant risk of tidal flooding.

7.147 Even allowing for the predicted effects of climate change to year 2115, Flood Risk Category 3 would extend to much the same extent as the present day situation and the remaining parts of the study area are still located within Flood Risk Category 1.

Flood Risk to Downstream Areas

7.148 Development within the 'greenfield' northern part of the study area could increase surface water runoff into the Pierpoint and Middleton Stop Drains. Increased flow within these drains would inevitably cause extra pumping costs at Pierpoint Pumping Station and reduce the standard of protection provided by this pumping station. This would, in particular, increase flood risk within the Hardwick Industrial Estate.

7.149 Urban development on the southern side of Constitution Hill could also substantially increase runoff from the hillside towards the A10 and West Winch. Since there are no obvious drainage paths beneath West Winch Road (A10) this additional runoff poses a potential flood risk to properties along West Winch Road. The discharge of substantial quantities of additional runoff into the Puny Drain system would have implications for flood risk within that catchment as well as increased pumping costs at the new outfall pumping station at Saddlebow.

7.150 It is therefore important that any development within the study area should be routed through flow attenuation devices and flood storage lagoons to avoid increasing rates and volumes of surface water runoff and hence flood risk, both within and downstream of the study area. It should, however, be noted that the soils on both sides of Constitution Hill are of soil types that are likely to be fairly permeable, and hence the use of Sustainable Drainage Systems (SUDS) is likely to be effective in increasing infiltration and reducing runoff from urban development in this study area.

NORTH & SOUTH WOOTTON (KL8)

General Description of the Study Area

7.151 The North & South Wootton study area takes the place of the Wooton Marshes study area in the original SFRA, but whereas the Wootton Marshes study area was situated entirely to the west of the old Kings Lynn to Hunstanton railway line the old railway now forms the western boundary of the new study area. North and South Wootton are two contiguous villages on the northern outskirts of Kings Lynn but which have effectively become a suburban extension of the town. A plan of the study area is given in Figure 7.8.

7.152 The North & South Wootton study area, the smallest of the Kings Lynn study areas, covers 115 hectares and is located 4km north of the centre of Kings Lynn. The study area occupies a long and gradually narrowing corridor of land running north from the A1078 road to North Wootton church. The study area's eastern boundary follows the winding line of Nursery Lane over its whole length in both South Wootton and North Wootton. The A1078 (Low Road) forms the area's southern boundary and North Wootton Station Road its northern boundary.

7.153 Although much of the built-up area in both North and South Wootton lies to the east of Nursery Lane a substantial portion of the built-up area falls within the study area. Even so, more than half of the study area consists at present of mixed farmland, both arable and pasture, and this 'greenfield' land is concentrated along the western side of the study area.

7.154 North and South Wootton are situated at the foot of the ridge of high land which runs south from Castle Rising to the Gaywood River. The ridge rises to its maximum elevation at Knights Hill (51mOD), 2.5km east of Wootton, from where the land falls steadily westwards to Wootton Marshes. Along the eastern boundary of the study area ground levels undulate between 5mOD and 12mOD, marginally higher towards the south. Along the area's western boundary, within the eastern edge of Wootton Marsh, ground levels are much more uniform, at or marginally below 5mOD.

7.155 Most of the study area falls within the Kings Lynn Internal Drainage District, with the exception of the Hall Lane / Church Lane area of South Wootton and a small area of higher land south of Ryalla Drift and two isolated pockets of land west of Nursery Lane in North Wootton. The IDB area extends east of the study area along the valleys of both small streams; up the northern stream to Wootton Park and up the southern stream as far east as Castle Rising Road.

7.156 The Environment Agency's Flood Map shows about a third of the study area to be in Flood Zone 3. The Zone 3 area is confined largely to the marshland east of the old railway line but includes property on the west side of Wheatley Drive. It should, however, be noted that the EA's Flood Map now shows the Zone 3 land in Wootton Marsh as "defended".

Hydrology of the Study Area

7.157 The study area is intersected by two small streams which flow west from the Knights Hill ridge towards Wootton Marsh, passing through the built-up areas of North and South Wootton before they reach the study area. The drainage pattern given by the FEH database does not correspond with the actual topography and network of minor watercourses in the locality shown on OS maps of the area, but the catchment areas of these two small streams are both less than 2 sq.km.

7.158 Both these two streams merge at a point on the east side of the old railway line, to form the North Wootton Drain, an IDB-maintained watercourse, which runs northwest across Wootton Marsh and discharges to the Babingley River at the acute bend in the river.1.5km west of North Wootton church. Babingley River, a Main River of the Environment Agency, discharges through its outfall sluice to the tidal estuary of the Great Ouse 4km downstream on Kings Lynn.

7.159 The smaller and more northerly of the two streams rises on Ling Common and crosses the study area at the southern end of Manor Road, west of Wootton Park. This stream is an IDB drain for 400m from Rill Close to its confluence with the southern stream.

7.160 The more southerly of the two streams rises on South Wootton Common and crosses the study area at the bend in Nursery Lane, 400m north of South Wootton church. Plans provided by the IDB show that this stream is an IDB-maintained watercourse not only to the boundary of the Internal Drainage District at Castle Rising Road but continues as an IDB-maintained watercourse (Rainbow Drain) as far upstream as the A148 (Grimston Road).

7.161 The catchments of both small streams consist of light sandy or loamy soils typical of the common and heathland on the western side of Knights Hill. Apart from local runoff from suburban development in the villages themselves, the response of the two highly permeable catchments to storm rainfall will be relatively sluggish, with the streams exhibiting long, relatively flat hydrographs very similar to those of chalk catchments.

7.162 On the eastern edge of Wootton Marsh the soil changes to a silty calcareous alluvial soil, but one that is still fairly permeable, so the use of Sustainable Drainage Systems (SUDS) techniques (see Section 8) for the attenuation and disposal of urban runoff should be feasible throughout the study area.

7.163 There are no particularly large surface water sewers in North and South Wootton. Most of the more recent housing developments east of Priory Lane in South Wootton do not have public surface water sewer systems and it is assumed that runoff from individual properties is disposed of to soakaways into the study area's highly permeable subsoil. In North Wootton two 600mm sewers, one from All Saints Drive and one from Wootton Park, discharge to the North Wootton Drain at Nursery Lane. On the southern boundary of the study area a 450/525mm surface water sewer /road drain runs west along the south side of Low Road.

7.164 Foul sewage from North and part of South Wootton is drained or pumped to a sewage pumping station in Wootton Park, from where it is pumped in twin 250mm pipes along Nursery Lane to Ryalla Drift where the two pipes turn west as far as the old railway line, then south along then old trackbed to Edward Benefer Way, and then along the line of that road towards the Kings Lynn dock area in a rising main. Foul sewage from the southern part of South Wootton drains to the head of a 375mm gravity sewer at the junction of Hall Lane and Low Road from where it continues south into North Lynn.

Flood Risk within the Study Area

7.165 The principal source of flood risk to the study area will be tidal flooding from the tidal outfall channel of the Great Ouse and its estuary at the point where it enters the Wash. However the distance of the study area from the primary defence line - between three and four kilometres – and the presence of old secondary and even tertiary tidal defence lines on Wootton Marshes ensure that the study area is well beyond the limit of the hazard zone.

7.166 The Strategic Flood Risk Map (Fig.5.1) shows that, taking existing flood defences into account, the whole of the study area is in Flood Risk Category 1. Even allowing for the predicted effects of climate change to year 2115, Flood Risk Category 3 would extend only as far inland as the old railway line, with Category 2 encroaching up to 200m east of the line but as far inland as Nursery Lane along North Wootton Drain.

7.167 Although the classification of the relatively low-lying western part of the study area as Category 1 land is justified by the standard of defence provided by the tidal defences along the east side of the Great Ouse tidal outfall channel, the existence of the low railway embankment along the study area's western boundary also provides a significant degree of protection against tidal flooding. This protection could be further increased by the installation of a flap valve at the culvert which conveys the North Wootton Drain beneath the railway.

7.168 There must inevitably be some risk of flooding from the two small streams which flow from east to west through the study area but this risk will be minor because of their very small and highly permeable catchments and their minimal floodplains. Any flooding from these streams would almost certainly be shallow and very localised.

7.169 Because of their modest size and limited catchment areas, the impact of any flood risk posed by Wootton's surface water sewers would be minor and very limited in extent. The equally minor residual flood risk from Wootton's foul sewerage system is confined primarily to the area around the Wootton Park pumping station and the short length of twin rising main between Wootton Park and Ryalla Drift.

Flood Risk to Downstream Areas

7.170 It is assumed that the majority of surface water runoff from any future urban development in this study area will be discharged, directly or indirectly, to the North Wootton Drain. It is possible that some runoff from the southwestern corner of the study area may drain to the North Lynn Drain. It would be preferable to discharge runoff from the study area to North Wootton Drain rather than to the North Lynn Drain as the latter is pump-drained.

7.171 West of the old railway line the North Wootton Drain and the Babingley River, into which it flows, pass through Wootton Marsh, an extensive area of farmland with hardly any residential property. Even if additional unattenuated runoff from the study area was discharged to this drainage system, the impact of any increased flood risk would be minimal. Conversely the North Lynn catchment includes a significant area of industrial development on the northern edge of the town which is another reason to avoid, if possible, discharging any additional runoff from the study area to that catchment.

7.172 In practice, the prevailing characteristics of the soil and subsoil in the study area are highly suitable for the incorporation of SUDS into the surface water drainage systems associated with future development. It should therefore be possible to achieve a high degree of attenuation of any additional runoff discharged from the study area and effectively eliminate any increase in flood risk to downstream areas.

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Study Areas in Downham Market

7.173 Two of the eleven study areas in the Borough are situated in Downham Market (Figure 1.2.2). These two large study areas run north and south respectively from Railway Road and together cover almost all the remaining open land on the west side of the town, between the town and the Relief Channel. Each study area consists principally of "greenfield" land but also includes a substantial amount of miscellaneous commercial and light industrial land on the western edge of the town.

7.174 Downham Market is situated to the east of the tidal outfall channel of the Great Ouse, 3km north (downstream) of Denver Sluice. It is a small market town (population 6,800) and service centre for a substantial area of south west Norfolk. The town has developed on the eastern slope of the river valley down to the edge of the floodplain between the 5m and 40mOD contours. When the railway between Ely and Kings Lynn was built in 1846 it was routed between the town and the river, with a station on the western edge of the town. The railway station then provided a focus for commercial and light industrial development, notably flour milling, on that side of the town. More recent light industrial development or redevelopment has also taken place in this area of the town, with modern residential development spreading to the north and south of the town.

7.175 The River Great Ouse has always been the dominant hydrological feature of the town. The only other natural watercourses in the area are a number of small streams that flow west down the valley side towards the Great Ouse. Any that flow through the town have been culverted. In the late 1950s / early 1960s the Relief Channel (see Section 5) was excavated in the narrow strip of floodplain between the tidal river and the railway. The new channel is larger than that of the tidal river and now effectively forms the western limit of the town. Excavation of the new channel produced large quantities of surplus spoil which was deposited along the banks of the channel. These spoil banks have the appearance of floodbanks but in the Downham area they are discontinuous and do not fulfil that function.

7.176 The most low-lying land along the east bank of the Relief Channel is in the Stoke Ferry Internal Drainage District which, in the Downham Market area, extends from the River Wissey as far north as Stow Bridge. Two of the watercourses in the study areas, Gooles Run and Sewer Run, are IDB-maintained drains. On the far side of the tidal River Great Ouse there is an extensive area of pump-drained fenland extending west to the River Nene.

7.177 Only a few large surface water sewers are shown on the Anglian Water sewer plans of the town and these are all in the newer residential areas to the north and south of the town. All the sewers in the older, central part of the town are shown as foul sewers. Rather surprisingly, no combined flow (foul and surface water) sewers are shown. This leaves unresolved the question as to how the surface water runoff from the town centre is disposed of, as it is most unlikely that anything other than a small proportion of this runoff will drain to soakaways.

7.178 It is possible that some of what are shown on the sewer plans as foul sewers are, in reality, combined sewers. This suspicion is reinforced by the existence of an overflow from a "foul" sewer to a surface water sewer in Lynn Road, discharges from surface water to foul sewers shown in London Road and Church Street, and the presence of two major (600mm) "foul" sewer outfalls to the Relief Channel on either side of Hythe Bridge.

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DOWNHAM NORTH WEST (DM1)

General Description of the Study Area

7.179 The Downham Market North West study area is a large (85 hectares) irregularly shaped area of land to the north west of Downham Market. The area is bounded by the Relief Channel on the west and Railway Road (B1512) on the south. The area's northern boundary is an approximate westwards extension of the northern edge of Kingston's Plantation, a block of woodland that lies in the NE corner of the study area. Except in the Station Road area, the irregular western edge of the extensive block of modern housing development west of Lynn Road forms the study area's eastern boundary.

7.180 The southern end of the study area includes a variety of light industrial and commercial premises off Fairfield Road, west of the railway, and Bennett Street, east of the railway. It also includes Downham Market railway station, two streets of Victorian terraced housing off Bennett Street, and a substantial area of more recent housing along Elizabeth Avenue, Nelson Avenue, The Paddocks and Broadlands. Anglian Water's large Downham Market sewage treatment works occupies a considerable area of land near the centre of the study area. A plan of the study area and its surroundings is given in Figure 7.9.

7.181 Apart form the sewage works and a small electricity sub-station, the land that constitutes the northern and central parts of study area is entirely "greenfield" in character except for an abandoned junkyard and disused agricultural buildings NW of the sewage works. To the south, east and immediately to the north of the sewage works this land is now either pasture, rough grazing or abandoned and reverting to scrub. At the northern end of the area, south and west of Kingston's Plantation, there are a number of arable fields. Fairfield Road extends north from the railway station as an access road to the sewage works, and a green lane, Cock Drove, runs east from Fairfield Road across the centre of the area.

7.182 The general slope of the land surface in the study area is from the higher land in the east down to the river in the west, with significant undulations along the north - south axis in the NE of the area between Cock Drove and Kingston's Plantation. Ground levels within the study area vary between 3m and 15mOD.

7.183 The great majority of the study area lies within the Stoke Ferry Internal Drainage District, except for a handful of fields on either side of Cock Drove east of the sewage works and the area of more recent housing north of Railway Road. The Environment Agency's Flood Map shows a small area of farmland north of the sewage works in Flood Zone 3 which also extends to the rear of industrial properties on the west side of Fairfield Road, west of the railway station.

7.184 In 2001 an application was made to the Borough Council for consent to develop most of the "greenfield" land between Bennett Street and Cock Drove for housing. A flood risk assessment was subsequently submitted in support of this application (Ref.11). The results and conclusions in that assessment report will be considered in detail in paras.7.190 and 7.191 below.

Hydrology of the Study Area

7.185 The most significant hydrological features of the study area are the tidal channel of the Great Ouse and the Relief Channel running in parallel along the western edge of the area, where the distance apart of the two channels varies between 50m and 220m. The Great Ouse is embanked along both banks, the crest level of the east bank being between 7m and 8mOD, well above the 200-year return period tidal flood level of 5.77mOD at Denver Sluice. There are spoil banks along the Relief Channel, mainly in the area between the two channels, but there is also an isolated spoil heap east of the railway at one point, between the railway and Fairfield Road.

7.186 The principal watercourses within the study area are the Sewer Run and the Fairfield Road Drain, both IDB-maintained. Sewer Run flows west from a surface water sewer outfall at the NW corner of Heron Close. The Fairfield Road Drain flows north from a point near the north end of Bennett Street alongside Fairfield Road and past the sewage works (from which it receives the treated effluent discharge) to a confluence with Sewer Run near the NW corner of the area. The combined drain passes under the railway in a culvert to a gravity outfall to the Relief Channel 20m downstream of the confluence.

7.187 Sewer Run flows in a substantial channel as far west as the dogleg north of the sewage works, at which point the channel section is reduced substantially and where (in December 2003) there was appreciable backing-up of water in the drain above the dogleg, with minimal freeboard between water surface and field level.

7.188 The Anglian Water sewer record plans show no surface water sewers within the study area, apart from a local system serving the urbanised area east of Bennett Street with a 270mm outfall into the Fairfield Road Drain. A 600mm surface water sewer from the Broomhill residential area on the northern edge of the town discharges into the top end of Sewer Run, and another 600mm surface water sewer discharges into the head of a tributary of the Fairfield Road Drain at the NW corner of Willow Road. Both outfalls are located on the eastern boundary of the study area.

7.189 A number of relatively small foul sewers cross the study area converging on the sewage works. Some of these are gravity flow, some pumped. None of these sewers is shown on the sewer plan as larger than 355mm diameter and none of these sewers are therefore considered to be large enough to pose a flood risk to the study area.

Flood Risk within the Study Area

7.190 The Woods Warren flood risk assessment report (Ref.11), based its assessment on the assumption of a breach in the east bank of the tidal river opposite the sewage works where the Great Ouse and Relief Channel are at their closest. It was assumed that the breach would occur at the peak of the 200-year tide and would remain open for the duration of the following high tide. Water would flow from the Great Ouse into the Relief Channel, causing the level of the water in that channel to rise, although the Environment Agency would operate the Head and Tail Sluices to minimise inflow to and maximise outflow from the Relief Channel until the breach was sealed.

7.191 The Woods Warren modelling involved a number of conservative assumptions, such as making no allowance for overspill of water from the Relief Channel or for the effect of the breach on water levels in the tidal river. The Woods Warren assessment concluded that the flood level in the Relief Channel would reach 2.70mOD on the first high tide, and a maximum of 3.19mOD on the second high tide. Assuming that the flood water would penetrate the area to which the 2001 planning application related, a narrow strip of land along the east side of Fairfield Road varying in width from 70m at Cock Drove to less than 20m at the level crossing would be inundated.

7.192 The probability of the Warren Woods flooding scenario materialising involves the coincidence of a 200-year tidal event with a breach directly opposite the study area, whereas in reality such a breach could occur on either bank of the tidal river anywhere between Denver and Saddlebow. This scenario is therefore that of a residual risk, with an annual probability somewhat less than 0.5%. However, although the tidal flood risk to the study area is essentially residual in nature, it could be compounded by 'floodlocking' and a conservative assessment is therefore justified.

7.193 The alternative flood risk scenario is fluvial flooding from the Relief Channel. The design flood level in the Relief Channel is 2.00mOD, based on the 1947 flood event to which it is difficult to ascribe a definitive return period. Above this level it may be assumed that the 'breaching sections' in the floodbanks at Denver will come into operation, as they would if flood water entered the Relief Channel from the tidal river - the Warren Woods scenario. It should, nevertheless, be assumed that the 100-year flood level in the Relief Channel, and hence the flood level on low-lying land to the east, may exceed 2.0mOD, given that the 1995 assessment ascribed a 50-year return period to this level.

7.194 Since it is assumed that fluvial flooding is more likely east of the Relief Channel than tidal flooding, even though the fluvial flooding may be due to tidal 'floodlocking', the primary flood risk in this area has been shown as fluvial on the Strategic Flood Risk maps (Fig.5.1). Nevertheless the whole of the study area is currently within Flood Risk Category 1. Although there is a local flood risk from the Sewer Run, during the December 2003 site inspection it was apparent that this risk can clearly be reduced by channel improvements at the downstream end of that watercourse. No part of the site is within a Hazard Zone.

7.195 The predicted effects of climate change cause a narrow wedge of land, widening towards the north, along the east bank of the Relief Channel to fall within tidal Flood Risk Categories 2 and 3, but the great majority of the study area will fall within Flood Risk Category 1. Any effect of increased flows due to climate change on flooding from of the Sewer Run / Fairfield Road Drain system, even during periods of 'floodlock', will similarly be secondary. The change, at strategic level, from fluvial flood risk at present to tidal flood risk in 100 years time should be noted.

Flood Risk to Downstream Areas

7.196 The whole of the study area drains to the Relief Channel, as well as the minor streams that flow through the study area from the higher land to the east. The combined storm runoff from the study area and the catchments of the minor streams will be wholly insignificant compared to the flow in the Relief Channel during a flood event. Any increase in flood risk to land and property downstream of the study area as a result of increased storm runoff from the developed area can therefore be effectively disregarded.

7.197 This does not, however, mean that additional urban runoff from newly developed areas, either in the study area itself or from areas locally upstream (i.e. east) of the study area, would not pose a flood risk to low-lying land within the study area if the Sewer Run / Fairfield Road Drain outfall was 'floodlocked' by high water levels in the Relief Channel, whether during a fluvial flood or as a result of tidal water entering the Relief Channel (see paras.7.191 & 7.192). Provision should therefore be made for storm runoff from any large scale development in the Sewer Run / Fairfield Road Drain catchment, including the study area, to be routed through flood storage lagoons or ponds, or pumped to the Relief Channel.

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DOWNHAM SOUTH WEST (DM2)

General Description of the Study Area

7.198 The Downham South West study area is situated to the south west of the town. It extends over an area of 59 hectares on either side of the Ely to Kings Lynn railway line. Railway Road (B1512) forms the northern boundary of both parts of the study area. The part of the study area west of the railway is bounded on the west by the Relief Channel and extends 1,200m south of Railway Road. The eastern part of the study area is bounded to the south by the Downham Market southern bypass (A1122) and to the west by the edge of the existing residential development west of London Road. A plan of the study area and its surroundings is given in Figure 7.10.

7.199 The town's southern bypass crosses the western half of the study area between Station Road and the A1122 level crossing. A new road, St John's Way (formerly Barton's Drove) heads south from a roundabout on the bypass at Barton's Farm and forms the spine road for what is becoming a new light industrial area south of Barton's Farm. At the north end of the strip of land between the bypass and the railway is a large flour mill. Apart from a chalet bungalow and electricity sub-station, the remainder of this strip is waste land. The strip of land on the opposite side of the road, between the bypass and the Relief Channel, is mainly rough grazing land. South of Barton's Farm, apart from a chilled foods warehouse at the northern end, the land is either abandoned farmland or rough grazing with a single arable field in the SW corner of the area. The parcel of land west of St Johns Way is at present littered with mounds of earth, another parcel of land at the south end of this road with disused 'portacabins'.

7.200 The eastern half of the study area includes the small Sovereign Way Industrial Estate north of the bypass, a miscellany of older commercial, residential and light industrial property in an area known as The Green south of Railway Road. Between The Green and Sovereign Way is the Willows Nature Reserve which includes a number of ponds.

7.201 The general slope of the land surface in the study area is also from the higher land in the east down to the river in the west, though much less steeply than in the Downham North West study area. Ground levels within this study area vary between about 1m and 15mOD, though the land above 5mOD is all east of the railway. The land west of the railway is virtually flat. Much of the land between St John's Way and the Relief Channel is between 1m and 2mOD, with ground levels rising to 3mOD between St John's Way and the railway (Ref.12). There is a small area of land below the 0mOD contour at the north end of Middle Drove, 500m south of the study area, so it is reasonable to assume that ground levels in the south of the study area may approach this level.

7.202 It is known that part of the Denver ‘washland’ lies east of the Relief Channel in the Middle Drove area. Emergency inflow to the ‘washland’ at times of flood is by means of ‘breaching sections’ in the banks of the Cut-Off Channel at Denver. There is a substantial earth embankment running across the study area on a dogleg route between the Relief Channel and the railway, immediately south of Gooles Run. If this embankment is the northern limit of the ‘washland’ then the southern end of the study area lies within the ‘washland’ and the functional floodplain.

7.203 Within the study area the boundary of the Stoke Ferry Internal Drainage District follows a line at about the 4mOD contour. North of the Barton’s Farm roundabout, the Environment Agency’s Flood Map shows Flood Zone 3 extending across the bypass and as far east as the flour mill. Barton’s Farm and the roundabout are in Zone 1, but south of the roundabout the Flood Map shows Zone 3 extending east to the line of St John’s Way and crossing it in the vicinity of Gooles Run.

Hydrology of the Study Area

7.204 As with the Downham North West study area, the most significant hydrological features of this study area are the tidal channel of the Great Ouse and the Relief Channel running in parallel along the western edge of this study area, only about 100m apart, though this distance increases to 300m at the southern extremity of DM2. Here too, the Great Ouse is embanked along both banks, and above the 200-year return period tidal flood level of 5.77mOD. There are spoil banks along both sides of the Relief Channel.

7.205 The principal watercourse within the study area is Gooles Run, an IDB-maintained drain. Gooles Run drains a relatively small catchment west of London Road (B1507) and north of Denver Sluice Road but one which includes a considerable built-up area on the south side of the town. The northern and southern arms of Gooles Run flow towards each other along the west side of the railway and, where they meet, are taken in a culvert under the railway from where the combined stream flows west to a gravity outfall to the Relief Channel at OS grid reference TF 597024. This outfall is not fitted with a non-return flap valve, but Gooles Run is embanked to a level of at least 2.0mOD on both banks through the low-lying land for a distance of about 300m from the outfall.

7.206 A recently enlarged drain serving the new industrial estate runs south from Barton's Farm to Gooles Run along the west side of St John's Way. This drain also serves the land between the bypass and Relief Channel north of Barton's Farm. A smaller tributary drains the low-lying land south of Barton's Farm. This drainage system has a penstock-controlled gravity outfall to Gooles Run just upstream of the Gooles Run outfall to the Relief Channel. It is understood that these two drains have recently been adopted by the Stoke Ferry IDB but, unlike Gooles Run, they are unembanked.

7.207 The Anglian Water sewer record plans show a 600mm surface water sewer which serves the extensive area of modern housing development between Richmond Road and Trafalgar Road discharging into the head of the open ditch along the south side of The Willows nature reserve. 160m further downstream this ditch, a tributary of the northern arm of Gooles Run, receives a 600mm outfall from Sovereign Way. Another 600mm surface water sewer which drains the new Crow Hall Park housing estate is shown discharging to a roadside ditch across the bypass from the southern end of Greenwich Close.

Flood Risk within the Study Area

7.208 The Woods Warren flood risk assessment report (Ref.11) was made specifically for land within the Downham North West study area and has been considered in detail above. The principles of that assessment are, nevertheless, broadly applicable to this study area in that if tidal flood water were to enter the Relief Channel through a breach in the east bank of the Great Ouse then water could potentially rise to a level of 3.2mOD in the Relief Channel and any watercourses in hydraulic continuity with the Relief Channel. The outfall from Gooles Run to the Relief Channel does not appear to be fitted with a non-return flap valve, so that water could flow unimpeded from the Relief Channel into Gooles Run.

7.209 Under these circumstances much of the whole of the study area west of the railway except at the northern end towards Hythe Bridge and the flour mill would be flooded. (It is assumed that most of the land south of Barton's Farm is below 3mOD.) The extent of this flooding could, however, be reduced by ensuring that Gooles Run and any other gravity outfalls to the Relief Channel are fitted with flap valves.

7.210 As with the Downham North West study area, the tidal flood risk to this study area is essentially residual in nature, with an annual probability of less than 0.5%, though it could be compounded by 'floodlocking'. Here again, as it is assumed that fluvial flooding is more likely east of the Relief Channel than tidal flooding, even though the fluvial flooding may be due to tidal 'floodlocking', the primary flood risk in this area is shown as fluvial on the Strategic Flood Risk maps.

7.211 If fluvial flooding form the Great Ouse system is considered, the 100-year return period flood level in the Relief Channel is believed to be 2.0mOD though there is a possibility that it could be higher. This would also cause 'floodlocking' in the study area but to a considerably lesser extent than the tidal flooding scenario described in paras.7.208 and 7.209 above. The absence of a flap valve at the Gooles Run outfall would permit backflow from the Relief Channel but this would be contained within its embanked section although backflow into the St John's Way drainage system would occur if the penstock at the outfall from these drains to Gooles Run were not closed in time. The installation of a flap valve or small land drainage pumping station at this outfall should therefore be considered.

7.212 There is a significant difference between the Downham North West and South West study areas in that the low-lying land in Downham South West is both lower, possibly by as much as two metres, and far more extensive than that in that in Downham North West. This means that the risk of 'floodlocking' and the associated secondary flooding in this study area is considerably more than that in Downham North West. There is also the question of the proximity of this study area to the Denver 'washland' (see para.7.202) and even the possibility that the southern end of the study area may actually be situated within the functional floodplan. Both these factors reinforce a fluvial flood risk classification.

7.213 It can thus be concluded, as is shown on the Strategic Flood Risk map (Fig.5.1), that the majority of this study area west of the railway and to the south of Barton's Farm falls within fluvial Flood Risk Category 2. The remaining parts of the study area are in Flood Risk Category 1. The southern part of the study area south of Gooles Run is located in the Hazard Zone due to the land's low lying nature.

7.214 The predicted effects of climate change on flood risk in the study area cause the whole of the area to the west of the railway to be within tidal Flood Risk Category 3, apart from the flour mill to the south of Railway Road. A small piece of land to the east of railway at the northern end of Sovereign Way will be in Flood Risk Category 2. The rest of the study area will still be in Flood Risk Category 1. The switch from fluvial flood risk at present to tidal flood risk 100 years from now should be noted.

Flood Risk to Downstream Areas

7.215 The whole of the study area drains to the Relief Channel, as well as the higher land east of the study area which forms the Gooles Run catchment. As with the Downham North West study area, the combined storm runoff from the study area and the Gooles Run catchment will be wholly insignificant compared to the flow in the Relief Channel during a flood event. Hence any increase in flood risk to land and property downstream of the study area as a result of increased storm runoff from the developed area can, for all practical purposes, be disregarded.

7.216 This does not mean that additional urban runoff from newly developed areas, either in the study area itself or in the Gooles Run catchment upstream (i.e. east) of the study area, would not pose a flood risk to low-lying land within the study area if the Gooles Run outfall was 'floodlocked' by high water levels in the Relief Channel, whether during a fluvial flood or as a result of tidal water entering the Relief Channel (see paras.7.190 & 7.191). Provision should therefore be made for storm runoff from any large scale development in the study area and the Gooles Run catchment to be routed through flood storage lagoons or ponds or pumped to the Relief Channel.

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HUNSTANTON (HN1)

General Description of the Study Area

7.217 The town of Hunstanton is situated on the eastern shore of the Wash, 21km north of Kings Lynn, as shown in Figure 1.2.3. Hunstanton is primarily a seaside resort and most of the town lies along the 500m strip of land between the main A149 road and the shoreline. Unlike Kings Lynn and Downham Market, the Hunstanton study area was not included in the original Kings Lynn & West Norfolk SFRA.

7.218 Most of the elongated but irregularly shaped 229 hectare study area is located west of the A149 road but includes recent development east of the main road and north of Downs Road as well as some undeveloped land up to the parish boundary between Pine Close and Chapel Bank. South of Downs Road the A149 forms the study area's eastern boundary. The southern boundary of the study area follows the Hunstanton / Heacham parish boundary. The separate village of Old Hunstanton, situated just beyond the northeastern edge of the town, is not included in the study area. A plan of the study area is given in Figure 7.11.

7.219 The chalk ridge that runs from south to north up the western side of East Anglia passes through West Norfolk and reaches the coast at Hunstanton, reappearing on the north side of the Wash as the Lincolnshire Wolds. Over geological time the chalk ridge has been slowly eroded and on the eastern side of the Wash it now terminates as a line of low cliffs, some 3km in length. In the nineteenth century Hunstanton was established as a seaside resort on the elevated land above the cliffs, overlooking the mouth of the Wash. The original village of Old Hunstanton lies at the northern end of the line of cliffs northeast of St Edmund's Point, where the Wash meets the North Sea.

7.220 The cliffs begin at Seagate Road and rise steadily to reach their maximum height of about 20mOD between Lincoln Square and St Edmund's Chapel before diminishing and merging into the sand dunes at Hunstanton Golf Club. Within Hunstanton the land rises to 34mOD along the A149 (Cromer) road on the eastern edge of the town. The broad chalk plateau so formed and along which the main road runs extends from the northern end of the town (Lighthouse Lane) to the junction of Oasis Way (B1161) and the A149 at the top of Redgate Hill at the southern end of the town.

7.221 Although the great majority of the Hunstanton study area - the town's principal residential and shopping areas - is above the 10mOD contour, there is a considerable area of land at the southern end of the town in the Hunstanton South Beach area which lies below the 5mOD contour. This area consists mainly of holiday accommodation (including caravan sites) and associated recreational and entertainment activities.

Hydrology of the Study Area

7.222 In northwest Norfolk the chalk ridge, upon the seaward end of which Hunstanton is situated, has been considerably incised by the many small rivers and chalk streams which flow west to the Wash or north to the North Norfolk coast. To the east of Hunstanton the River Hun flows northwards from Ringstead Downs to Old Hunstanton. To the south of Hunstanton the larger Ringstead River flows west from Docking to the foot of Redgate Hill, merging with the Heacham River and entering the Wash at Heacham. Hunstanton therefore stands on an elevated chalk 'island', partially isolated from the main body of the chalk ridge by valleys to the east and south.

7.223 The River Hun rises on Ringstead Downs and, fed by chalk springs, flows north through the wooded grounds and parkland of Hunstanton Hall. The western edge of its catchment is roughly coincident with the A149 road. The river flows beneath the A149 at Gipsy Green on the eastern side of Old Hunstanton, upstream of which its catchment area is 5.4sq.km.

7.224 Downstream of Gipsy Green the River Hun enters the coastal plain east of Old Hunstanton and runs NE for 4km through the low-lying marshes and parallel with the coast before discharging to the North Sea through a tidal outfall sluice at Thornham. Although the River Hun poses no flood risk whatsoever to the study area its location relative to the town influences the surface water drainage pattern of the study area.

7.225 Upstream of the A149 at the foot of Redgate Hill, the Ringstead River drains a catchment area of 40.8sq.km which consists largely of intensively farmed arable land on the gently rolling chalk downs. However over the 4km between Redgate Hill and Ringstead village the river channel is deeply incised into the chalk, leaving a narrow col between itself and the head of the River Hun. Despite the considerable size of its catchment, the river itself rises from chalk springs at Ringstead Downs Farm which is only 1,100m upstream of the A149 at Redgate Bridge. Above this point the catchment's main and tributary valleys are all either dry valleys or ephemeral bournes.

7.226 Downstream of Redgate Bridge the Ringstead River heads south into the coastal plain, away from Hunstanton. It joins the Heacham River west of Heacham Park and the combined watercourse enters the Wash through a tidal outfall sluice at Heacham South Beach. The Ringstead River flows along the southern boundary of the study area for a distance of only 300m and would only pose a localised flood risk to land below the 10mOD contour in its immediate vicinity but, like the River Hun, its location influences the surface water drainage pattern of the study area.

7.227 A small area of low-lying land in the south western corner of the study area falls within the Kings Lynn Internal Drainage District. South of Bishops Road there are substantial drainage ditches alongside the old railway line. North of the Heacham parish boundary (i.e. within the study area) these ditches connect into Searles Drain, a Kings Lynn IDB drain, which has a gravity outfall to the Wash at Heacham South Beach. South of the study area the more westerly railway ditch ("the Reservoir") has been adopted as an IDB drain and flows south to the Heacham River.

7.228 Hunstanton's urban surface water sewerage system consists largely of a series of seven small systems draining westwards to the cliff where they discharge into the Wash between the old lighthouse and the Lesiure Centre. The discharge pipe sizes range from 225mm to 375mm with the exception of the 525mm pipe which outfalls west of The Green. This outfall also includes storm overflow from the town's main foul sewer. South of the Leisure Centre there are two very small surface water discharges along Seagate Road. At South Beach there is a 675mm storm overflow from the sewage pumping station at the Oasis Way roundabout.

7.229 There are three surface water sewerage systems which do not discharge directly to the Wash. The modern residential development south of Oasis Way and west of Redgate Hill drains into the top end of the IDB's Searles Outfall through a 600mm pipe at Manor Road, and to the head of the IDB's Reservoir Drain through a 750mm pipe. On the western edge of the town, surface runoff from the recent Campbell Close housing estate drains through a 450mm pipe towards Hunstanton Park and the River Hun. None of the other urban developments east of the A149 road has any surface water sewerage.

7.230 The principal component of Hunstanton's foul sewerage system is a 300mm interceptor sewer which runs south under gravity along Cliff Parade to The Green where it receives the pumped inflow from a 225mm foul sewer from Old Hunstanton and increases in size to 450mm. The interceptor sewer continues south to Seagate where it expands to 600mm as far as the main sewage pumping station at the Oasis roundabout, from where the town's sewage is pumped to the treatment works at Heacham.

Flood Risk within the Study Area

7.231 The Environment Agency's Flood Map shows a small area in the south western corner of the study area to be in Flood Zones 2 and 3 in the absence of any defences. The Flood Zone 3 area, which extends in a wedge along the coastline as far north as the Leisure Centre, is confined largely to land below the 5mOD contour. The only significant Flood Zone 2 areas are a pocket of land west of Bishops Road and the Ringstead River floodplain downstream of Redgate Bridge. The Flood Map shows a puzzling 'island' of 'defended' land within Zone 3 straddling the southern boundary of the study area west of the old railway line, but it appears to have no correlation with the actual flood defences in the area.

7.232 However the Strategic Flood Risk Map shows that, taking existing flood defences into account, the whole of the study area, apart from the south western corner, is in Flood Risk Category 1, leaving a small area, similar in extent to that on the Flood Map but going no further north than South Beach Road, in Flood Risk Category 2.

7.233 With the predicted effects of climate change to year 2110 taken into account, flood risk in this low-lying SW area increases to Category 3, with a narrow fringe of Category 2 land penetrating about 30m further inland. Because of the proximity of the flood risk area to the defence line, much of the area falls within the Hazard Zone (although as the defences are 'hard' the probability of a breach is very small). The Hazard Zone extends only as far north as South Beach Road.

7.234 The low-lying land in the South Beach Road area is protected from tidal flooding by the 'hard' concrete sea defences which now extend the whole distance along the Wash coastline from Heacham to the southern end of the cliffs at Hunstanton. These modern defences have been designed to withstand a 200-year return period event. (It is understood that the Hunstanton South Beach defences have been strengthened since the original SFRA was published.) In a less extreme storm tide event, even though severe wave action could result in sea water overtopping the defences on the crest of waves, the actual volume of water coming over the defences would be minimal and would create no significant flood risk to land behind the defences.

7.235 The Borough Council maintains a public flood warning siren at Hunstanton South Beach which, in anticipation of an extreme storm tide event, would be sounded to give advance warning of impending flooding to local residents and occupants of the holiday caravans in the area. (It is believed that the flood warning sirens in this study area may now be maintained by the Town Council.) It should be noted that although there are a number of large holiday caravan sites in the South Beach Road area, these are occupied principally during the summer months when the seasonal probability of flooding is much less than it is in the winter months (Ref.3b). There are relatively few permanent residents in the South Beach Road area of Hunstanton.

7.236 The risk of flooding from the Kings Lynn IDB drains in the South Beach area is small, and any fluvial flooding that did occur would result from the slow overtopping of the IDB drains giving rise to shallow flooding on the lowest land towards the Heacham River (well outside the study area) and mere waterlogging elsewhere.

7.237 Flooding from the Ringstead River along the southern boundary of the study area downstream of Redgate Bridge would be confined to land below the 10mOD contour in the river's widening floodplain below the bridge. In any case, because the river is fed almost entirely by chalk springs a kilometre upstream its flood hydrograph will have an exceptionally elongated shape and a correspondingly low, flat flood peak.

7.238 None of the surface water sewers described in paragraphs 7.228 and 7.229 above is considered to present a significant flood risk in Hunstanton. The town's foul sewerage system also presents no significant flood risk and any flooding from it would have a local sanitary impact only.

Flood Risk to Downstream Areas

7.239 Since the great majority of the study area is already urbanised, the only significant areas of 'greenfield' land that could be developed are the land east of the A149 (Cromer Road) in the north of the study area and the much smaller area of land at the foot of Redgate Hill. The possible flood risk to areas downstream of these potential developments are discussed separately below. At present urban runoff from Hunstanton drains mainly westwards to the coast and poses no risk whatsoever to land and property downstream.

7.240 The northern development area identified above is situated on elevated but fairly level land on the chalk ridge and the local topography suggests that surface water runoff from urban development could be drained either west to the coast or east to the River Hun. The former would of course be preferable. Any discharges to the River Hun should be in the Gipsy Green area, downstream of Hunstanton Park and its water features. Additional runoff discharged to the river should have no effect on property in Old Hunstanton and by the time it reaches Holme-next-the-Sea the runoff peak should be too attenuated to have any impact on property near the river there. However, the location of the northern development area on a highly permeable chalk ridge means that it should be admirably suited to the effective on-site attenuation of urban runoff by means of SUDS.

7.241 It must be assumed that surface runoff from any development in the Redgate Hill area, whether or not it is attenuated by SUDS, must eventually discharge to the Ringstead River. Between Redgate Bridge and its confluence with Heacham River, the river flows through a golf course with no adjacent property except Heacham Manor Farm. Downstream of the confluence the small volume of runoff would be so attenuated by inflows from the much larger Heacham River that any impact within the wide river channel at Heacham North Beach (sized to allow for storage of runoff during tidelock periods) would be too small to have any effect on flood risk there.

8 Planning Policy and Flood Risk

East of England Regional Strategy

8.1 The East of England Region, one of the largest of the English regions, has a population of 5.5 million and stretches from the northern fringe of London to the North Norfolk coast. It includes the counties of Norfolk, Suffolk, Essex, Cambridgeshire, Bedfordshire and Hertfordshire. The East of England Regional Assembly (EERA) has the overall responsibility for spatial planning at the regional level.

8.2 EERA has produced the East of England Plan and the latest draft revision to the Regional Spatial Strategy (RSS) was issued in May 2008 (Ref.13). The RSS document includes a section on the future provision of housing in the Region to meet predicted population changes and growth forecasts. Policy H1 requires local planning authorities to 'facilitate the delivery of at least 508,000 net additional dwellings over the period 2001 to 2021.'

8.3 Housing development forms the principal component of urban development and regional forecasts of housing allocations between sub-regions and local planning authorities gives a broad indication of the areas where flood risk may be a constraint to growth but where large scale urban development could have a significantly adverse impact on flood risk elsewhere. It is therefore necessary to consider proposals for future urban growth on a regional scale, not only within local authority areas but within neighbouring areas.

8.4 Within the region (excluding those parts of Bedfordshire within the Milton Keynes South Midlands sub-region) these dwellings will be distributed as follows :-

Sub-Region	Annual Average	Total (2001 – 2021)
Norfolk	4,160	78,700
Suffolk	3,210	61,700
Essex (incl.Thurrock & Southend)	6,580	127,000
Cambridgeshire (incl.P'boro)	5,290	98,300
Bedfordshire (incl.Luton)	3,200	59,100
Hertfordshire	4,380	83,200
Totals	26,820	508,000

Table 9.1 - Future Housing Development in the East of England

8.5 Within Norfolk the allocation of housing growth between the various Local Planning Authorities (LPAs) within the county, including Kings Lynn & West Norfolk, is shown in Table 9.2 on the next page. The relatively small allocation to many LPAs is notable, and the largest allocation is to one of Kings Lynn & West Norfolk's neighbours, Breckland District. The size of Kings Lynn's allocation places the Borough fourth out of the seven Norfolk LPAs.

Local Authority	Annual Average	Total (2001 – 2021)
Breckland	780	15,200
Broadland	700	12,200
Great Yarmouth	320	6,000
Kings Lynn & West Norfolk	**630**	**12,000**
North Norfolk	420	8,000
Norwich	710	14,100
South Norfolk	710	11,200
Totals	4,270	78,700

Table 9.2 - Future Housing Development in Norfolk

8.6 Because of its location at the downstream end of the Great Ouse catchment, parts of the Borough are vulnerable to the potential increase in flood risk resulting from large scale urban development outside its boundaries. On the other hand, as much of Kings Lynn & West Norfolk drains directly to tidal waters and as there are no LPA areas downstream of the Borough, large scale development in the Borough will have no impact whatsoever on flood risk elsewhere.

8.7 In 2007, within the context of their Regional Spatial Strategy, EERA published the East of England Housing Investment Plan for the period from 2008 to 2011 (Ref.14). This plan identifies specific strategic (i.e. major development) sites within the Region where short to medium term development is expected to take place. Three of the 25 strategic sites across the East of England identified in this document are in Norfolk. Two of these sites which dominate the Greater Norwich Sub-Regional Housing Strategy are on the outskirts of Norwich - Sprowston (Broadland) and Costessey (South Norfolk). The third site - the NORA Millennium Community - is in Kings Lynn & West Norfolk and is the only strategic site in the Rural East Anglia Sub-Regional Housing Strategy.

8.8 In the EERA Housing Investment Plan the NORA (Nar-Ouse Regeneration Area) Millennium Community site will have 900 dwellings. Construction is due to begin in 2009/10 with completion forecast for 2012/13. The document also states that outline consent for this site has been achieved. This strategic site is situated on brownfield land east of South Lynn, between the A148 road and the railway.

8.9 It is probable that Local Planning Authorities throughout the Region will, as a matter of course, ensure that these major urban developments incorporate Sustainable Drainage Systems (SUDS) and that appropriate physical features, such as adequate runoff retention storage and flow controls, 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 these urban developments to the rates and volumes of runoff which would have been generated by those 'greenfield' areas prior to urbanisation, taking into account predicted (PPS25) increases in runoff over the lifetime of the development.

Sustainable Urban Drainage Systems

8.10 Sustainable Drainage Systems (SUDS - also known as or referred to as Sustainable Urban Drainage Systems) (Ref.15) are frequently installed where there is a need to attenuate the additional surface water runoff generated by the impermeable surfaces of a newly developed urban area on what was previously 'greenfield' land. These impermeable surfaces include roofs, paved areas and roads or any surface through which the natural infiltration into the subsoil has been artificially impeded. SUDS may include retention ponds, lagoons, buried tanks or oversize sewer pipework, swales and hydraulic or mechanical flow controls.

8.11 SUDS are usually provided by the developer in compliance with planning consent conditions, imposed by the local planning authority (usually in consultation with the Environment Agency and/or Anglian Water) where they are considered necessary to attenuate the additional runoff from a development before it is discharged to the receiving watercourse or sewer. In many cases, especially that of residential development, the developer intends to sell the development to prospective purchasers of the houses, industrial units etc and has no wish to have any interest or involvement in the development thereafter.

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

8.13 This raises the question of the responsibility for the maintenance of SUDS, which may be of particular relevance where the development (e.g. a housing estate) ultimately becomes the property of numerous private individuals. Even where the outflow from a lagoon or retention pond discharges to a public sewer, it is usually found that the water company owning that sewer will be unwilling to accept responsibility for the lagoon. Similarly, even where the receiving watercourse is a Main River, the Environment Agency is unlikely to accept responsibility for any SUDS discharging to that watercourse.

8.14 In practice, unless the SUDS in question are to be effectively abandoned at the outset, its maintenance often inevitably devolves onto the local authority in the absence of any other appropriate body. The Borough Council should therefore be prepared for the necessity of accepting de-facto responsibility for many SUDS but should be aware of the need for financial or other provision to be made at planning stage for the long term maintenance of those installations.

8.15 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, especially in extreme events.

8.16 It is suggested that the applicability of SUDS in each of the varied and very different topographies that exist in the Borough should be considered in greater detail in a future Water Cycle Study of Kings Lynn & West Norfolk. It would also be advisable for detailed Surface Water Management Plans to be prepared for the urban areas of Kings Lynn, Hunstanton and Downham Market, including all major potential development areas around the periphery of those towns.

8.17 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, even if widespread urban development takes place in the Great Ouse or Ely Ouse catchments upstream of Kings Lynn & West Norfolk it should not have any substantial effect on fluvial flood risk in the Borough generally for the following reasons:-

- Both Kings Lynn and Downham Market are situated adjacent to the tidal outfall channel of the Great Ouse downstream of Denver Sluice within which the size of the channel renders fluvial flood risk secondary to tidal risk.
- Upstream of Denver Sluice, although the increased fluvial flood risk in the tidelocked river channels due to urbanisation upstream could have a significant impact on flood risk generally, the area over which this increased risk would have an impact is confined almost wholly to sparsely inhabited fenland.

9 Conclusions

9.1 In August 2005 the original Kings Lynn & West Norfolk SFRA was approved and signed off by the Environment Agency and has subsequently been used to inform the Council's planning polices. The Conclusions reached in paragraphs 11.3, 11.4, 11.5, 11.10 and 11.12 in that SFRA Report still apply unchanged.

9.2 By 2006, rapid advances in overland flood flow propagation modelling techniques (2D methodology), the availability of high-definition LiDAR topographical survey data across the Borough, and the publication in PPS25 of longer term forecasts of the effects of climate change on flood flows and tide levels, made it necessary for the Borough Council to commission a revised version of their original SFRA. A revision of the 2005 SFRA taking into account the changes outlined above was therefore commissioned by the Council in May 2007. The study undertaken to produce the revised SFRA Report utilised data and information which had only become available since 2005.

9.3 Studies and investigations undertaken in connection with this revised Report have identified a number of principal sources of potential flood risk that could give rise to serious flooding from rivers or estuaries in Kings Lynn & West Norfolk. These are the tidal outfall channel of the Great Ouse downstream of Denver Sluice, the Great Ouse / Bedford River system (predominantly fluvial) upstream of Denver, the Ely Ouse river system including the Relief Channel and the Cut-Off Channel, the River Nar, and the Middle Level arterial drainage network. Taking natural and man-made topographical features into consideration, the areas of influence of the principal flood risk sources have been defined. The tidal outfall channel of the River Nene is not considered to be a principal flood risk source in the Borough.

9.4 This Report has also identified tidal flooding from the Wash and, to a lesser extent, the North Sea as principal sources of potential flood risk in Kings Lynn and West Norfolk. Taking similar considerations into account, the areas of influence of these principal flood risk sources have also been defined.

9.5 This new study SFRA has enabled a revised set of eleven 1/25,000 scale maps covering the whole of Kings Lynn & West Norfolk Borough (Figure 5.1) to be prepared, showing an updated current estimate of actual flood risk at any point within the Borough. These maps should enable the Borough Council to determine both the actual and relative degree of flood risk to which different areas of the Borough may be subject, thereby enabling informed planning decisions, both strategic and site-specific, to be made and justified with greater confidence than previously. It is notable that the revised estimates of current flood risk are generally significantly lower than those shown on the original SFRA maps.

9.6 Additional sets of maps (Figure 5.2) showing estimates of predicted flood risk in the year 2115 have also been produced. These maps, which assume that the Borough's existing fluvial and tidal flood defences are maintained in their present state, suggest a substantial increase in flood risk across the Borough as a result of climate change over the next hundred years, by which time a much larger area of the Borough will be within flood risk Category 3. This increased risk can, however, be halted if the Borough's flood defences are improved in that period to maintain present defence standards.

9.7 A 'rapid inundation' or hazard zone has been defined the as the width of the strip of land immediately behind a flood defence line within which there would be a serious danger to life and limb in the event of that defence breaching during a flood event. In this study the Hazard Zone was defined as any area within which flood flow velocity (metres/second) was greater than 0.5 or the flood depth (metres) exceeded 0.25. 2D hydraulic modelling techniques were used to calculate the width of the rapid inundation zone and a set of maps showing the resultant Hazard Zones in the Borough is included as Figure 5.3.

9.8 In addition to the Strategic Flood Risk maps described above, this Report also contains more detailed flood risk assessments of eleven large study areas. Eight of these study areas are in and around Kings Lynn itself (including West Lynn). Two others are on the outskirts of Downham Market and final one comprises the town of Hunstanton.

9.9 For each study area the assessment includes a description of the extent of those parts of the study area which are considered to be within each of the three flood risk categories defined in this Report. The extent to which the Hazard Zone impacts on the study area is also discussed. Each assessment is accompanied by a 1/5,000 or 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.

9.10 The four Flood Risk Categories adopted for this study are, for consistency, numerically equivalent to the Flood Zones defined in PPS25. Although a substantial part of the Borough is deemed by the Environment Agency's Flood Map to fall within Flood Zone 3, when actual flood risk is considered, few of the study areas fall either wholly or partly within Food Risk Category 3. The revised SFRA shows that flood risk within Kings Lynn & West Norfolk is generally less than that indicated by the original SFRA.

9.11 In general, additional surface water runoff from future development within the eleven study areas should not pose any increase in flood risk to urbanised areas downstream because of the local topography and patterns of settlement. Surface water runoff discharges from all new development on 'greenfield' land should, nevertheless, be attenuated to existing 'greenfield' runoff rates by the use of Sustainable Drainage Systems (SUDS) to minimise the impact on arterial drainage systems and agricultural land.

9.12 The predominantly tidal nature of the flood risk in the northern part of the Borough and the likely future pattern of urban development in the area means that flood risk in this part of the Borough is not likely to be significantly increased by urban development. In the southern part of the Borough upstream of Denver Sluice where the Ely Ouse River system is a principal flood risk source, large scale urban development in the Cam catchment (such as that which could arise from future implementation of the M11 Corridor Sub-Regional strategy) could, if not strictly controlled, have a potentially significant impact on future flood risk in the Borough.

9.13 This Report identifies the importance of the continuing long term inspection and maintenance of SUDS installed in connection with urban development for runoff attenuation purposes. Since it is inevitable that in many cases the de-facto responsibility for this will devolve upon the Borough Council, adequate provision for the funding of this responsibility should be considered and secured at the planning stage.

9.14 It is hoped that this revised and updated Report will form a sound and reliable basis for Kings Lynn & West Norfolk Borough Council to make informed and confident decisions on planning issues, both at the strategic and site-specific levels, thereby reducing the time taken to reach decisions and the resources employed in reaching those decisions.

10 Recommendations

10.1 The fifth, sixth, seventh, eighth and tenth Recommendations made in the 2005 Report are considered to be still applicable as they appear in that Report. The first Recommendation in the 2005 Report is applicable with the deletion of the word “forthcoming” and the fourth Recommendation with the words “fifty years” replaced by “hundred years”.

10.2 In accordance with the findings of this study and the conclusions reached in Section 9 of this Report the following recommendations are made:

- That Kings Lynn & West Norfolk Borough Council utilise the set of eleven revised Strategic Flood Risk maps prepared for the Borough (Figure 5.1 in this Report) in devising strategies and policies for incorporation in their Local Development Documents.
- That the Borough Council are fully aware of the potential increase in tidal flood risk throughout the Borough as a result of climate change over the coming hundred years as illustrated in the set of eleven Strategic Flood Risk maps (Figure 5.2) showing the predicted extent of actual flood risk in the year 2015 if the Borough’s tidal flood defences are maintained in their present state.
- That the Borough Council take note of the extent of the Hazard (‘rapid inundation’) Zone within the Borough as shown on the set of eleven Hazard Zone maps (Figure 5.3), taking into consideration the definition of the hazard zone used in the derivation of those maps.
- That the flood risk assessments made for the eleven study areas identified in this Report be used to apply the sequential test and exception test advocated in Planning Policy Statement 25 (PPS25) in deciding the most appropriate areas for development and the sequence in which those areas should be developed.
- That because substantial improvements will be necessary to the Borough’s tidal flood defences, both along the shores of the Wash and within the tidal outfall channel of the Great Ouse, to maintain the standard of flood defence throughout the Borough at its present level, the Borough Council make vigorous and persistent representations to ensure that these improvements are made. These improvements should be implemented in a programme of works that will ensure that tidal defence standards are maintained at or above present (2008) levels and are not permitted to fall below present defence standards at any time in the coming hundred year period.
- That the Borough Council adopts the flood risk alleviation strategies suggested in this Report, particularly those involving Sustainable Drainage Systems (SUDS), for dealing with applications for planning consent from prospective developers and to assist developers in putting forward proposals in line with the Council's flood risk alleviation strategies.
- 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 Borough 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.
- It is recommended that the applicability of SUDS in each of the varied and very different topographies that exist in the Borough should be considered in greater detail in a future Water Cycle Study of Kings Lynn & West Norfolk.

- It is recommended that consideration be given to the preparation of detailed Surface Water Management Plans for the urban areas of Kings Lynn, Hunstanton and Downham Market, including all major potential development areas around the periphery of those towns.

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Figures

Photographs

Appendix A - The Brief

Appendix B
Conclusions & Recommendations in the 2005 Report

Appendix C
Strategic Flood Risk Mapping Methodology