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Breckland Strategic Flood Risk Assessment

2007 Update

February 2008

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2007 Update

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Summary

In June 2005 Mott MacDonald completed the Breckland Strategic Flood Risk Assessment (SFRA) for Breckland District Council, taking account of advice in Planning Policy Guidance 25 (PPG25). In December 2006, Planning Policy Statement 25 (PPS25) was introduced by the Central Government to replace PPG25. In July 2007, Breckland District Council commissioned Mott MacDonald to update the Breckland SFRA to comply with this revised policy document. The updated SFRA provides a detailed and robust assessment of flood risk and its implications for land use planning to inform the preparation of the Local Development Framework.

The Council's proposed growth areas are Thetford, Attleborough, Dereham, Swaffham and Watton. Thetford has been identified in 2006 by Central Government as one of 29 National Growth Points which have the potential to provide a total of 100,000 new homes in addition to those previously planned, and many new jobs over the next 15 years. Larger villages are also expected to accommodate development, and have been included in this study.

A considerable amount of data has been collected in order to inform the revised SFRA, including the Broadland Rivers CFMP and the Catchment Modelling of the River Yare.

In order to determine the main sources of flooding within the district, records of flooding from rivers, groundwater, land runoff, motorways, reservoirs and sewers have been collected from the Breckland District Council, the Environment Agency, the Internal Drainage Boards, the Highways Agency, and the Anglian Water. Additional flooding records have been identified in newspaper archives. From the analysis of flooding records, it has been assessed that fluvial flooding, surface water flooding, sewer flooding and flooding due to infrastructure failure are significant within the district. In particular, there are records of fluvial and sewer flooding in Thetford, records of fluvial flooding in Attleborough, records of surface water, sewer and fluvial flooding in Dereham, records of sewer and surface water in Swaffham, and records of sewer flooding in Watton.

Terrain data, hydraulic modelling data, channel survey data and river gauging data have been obtained from the Environment Agency, in order to enable hydraulic modelling and flood mapping to determine the PPS25 flood zones. The principal rivers within the district are the Rivers Nar, Wissey, Little Ouse, Thet, Blackwater, Tud, Wensum, Watton Brook and Wendling Beck. Flood mapping of these rivers and the ordinary watercourses in proximity to the proposed developments has allowed the identification of the proposed development areas which are at risk of flooding with a 1% annual probability, and therefore within Flood Zone 3. Most of the proposed development sites are not within Flood Zone 3. In Attleborough a few development sites are partially at risk of flooding from the Besthorpe Stream and the Attleborough main drain. In Dereham the development sites to the south and the west of the town are partially at risk of flooding from the River Tud and the Wendling Beck respectively. In Watton, development to the north of the town is partially at risk of flooding from the Watton Brook. Some development sites are also at risk of flooding from the drain network. Potential flooding from such drains is generally localised and development can occur provided that it is located 10 to 30m away from these drains.

The Environment Agency has supplied information on the location and magnitude of permitted discharges from existing sewage works serving the development areas. This data has been utilised to assess the flood risk implications of the potential increased discharges from the works to watercourses due to the proposed developments. All the existing sewage treatment works discharge into watercourses which are prone to flooding during a 1% flood event. Increasing the discharge to these watercourses would therefore increase their 1% flood extents. Our initial investigation shows that there could be a significant impact on existing developments in Attleborough and Thetford. Detailed assessments taking into account the nature and size of the developments should be carried out for the specific developments.

Runoff rates and volumes from the proposed developments have been assessed in order to quantify the need for infiltration and storage. PPS25 requires that the surface water drainage arrangements for any development site should be such that the volumes and peak flow rates of surface water leaving a developed site are no greater than the rates prior to the proposed development. The additional runoff volume per hectare is quite high for all proposed development sites, and particularly in Thetford, Swaffham, East Harling, Narborough and Weeting. This is because of the nature of their soils which are very permeable. The increased runoff should be compensated for with the use of Sustainable Urban Drainage Systems to re-enable infiltration.

Peak runoff estimates from the large-scale proposed developments in Thetford and Attleborough are high, and considerably higher than from other proposed developments in the district. This highlights the need for a particularly efficient surface water drainage strategy at these locations.

Impacts of climate change on the predicted fluvial flooding and runoff from the developments have been assessed for the developments' lifetime, which has been assumed to be at least 50 years. An additional 20% to 30% was added to the 1% design peak rainfall intensity, and 20% was added to the 1% design peak river flows used for the present day analysis.

Due to the small scale of flood risk within Breckland District, most of the proposed development sites are located within Flood Zone 1 For this reason there is no clear priority with respect to flood risk as to which site should be developed first. However within each proposed development area, there is a gradation of the flood risk, which should be assessed as part of site specific flood risk assessments.

Certain aspects of flood risk have been looked at in some detail within each proposed development area. Those sites that progress to development stage must be subject to a full site specific Flood Risk Assessment in line with policies and guidance relevant at that time.

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Acknowledgement:

All data provided by the Environment Agency which has been used in the compilation of this report remains the property of the Environment Agency and must not be relied on or used for any other project without the prior written authority of the Environment Agency being obtained.

1 Introduction

In June 2005 Mott MacDonald completed the Breckland Strategic Flood Risk Assessment (SFRA) for Breckland District Council (BDC), taking account of advice in the document Planning Policy Guidance 25: Development and Flood Risk (PPG25). Planning Policy Statement 25: Development and Flood Risk (PPS25) was introduced by the Central Government in December 2006 to replace PPG25. In July 2007, Breckland District Council commissioned Mott MacDonald to update the Breckland SFRA to comply with this revised policy document.

The SFRA is to provide a detailed and robust assessment of the flood risk and its implications for land use planning to inform the preparation of its Local Development Framework.

It is recommended in the Practice Guide Companion to PPS25 to carry out the SFRA at two levels. This document represents a complete updated Level 1 SFRA, including the findings and assessments of 2005, superseded where appropriate by the work undertaken in 2007.

The purpose of the Level 1 SFRA is to:

- Identify the areas at risk from all sources of flooding, including groundwater, surface water, reservoirs and sewers.
- Assess the fluvial flood risk to potential development areas within identified PPS25 flood zones.
- Identify the location of any flood risk management measures, including both infrastructure and the coverage of flood warning systems
- Assess the potential increase in flood risk to existing developments due to increased run-off from any future large scale developments and from extra discharge from wastewater treatment works.
- Assess the impact of climate change on the flood risk at allocated development sites over the likely design lifetime for key developments.

The Level 1 SFRA should provide the basis for applying the Sequential Test, on the basis of the PPS25 Flood Zones.

If the proposed developments could not be allocated in accordance with the Sequential Test, taking account of the flood vulnerability category of the intended use, it will be necessary to undertake a Level 2 SFRA, in order to provide the required information for the application of the Exception Test.

The updates from PPG25 to PPS25 are detailed in Section 1.1, Stage 3.

1.1 The Study Process

The Study has been carried out in three stages including the following activities: -

Stage 1 (2005)

- Data collection and initial review

- Review of recent flood events
- Review of the watercourses maintained by BDC
- Review of present and proposed land use
- Assessment of adequacy of data to carry out SFRA
- Agreement of SFRA methodology
- Draft Stage 1 Report
- Meeting with Council and Environment Agency (EA) to consider draft
- Final Stage 1 Report

Stage 2 (2005)

- Overall strategic assessment of the flood risk, following the Guidance for Strategic Flood Risk Assessments issued by the EA
- Hydrological and hydraulic modelling of Main Rivers where necessary to complete coverage for study areas
- Determination of Standard of Protection for ordinary watercourses for study areas
- Flood risk mapping with PPG25 Flood Zones and other detail
- Assessment of development impact on discharge from sewage works to local watercourses
- Draft Stage 2 Report and Mapping
- Meeting with Council and EA to consider draft
- Final Stage 2 Report and Mapping

Stage 3 (2007)

- Additional data collection and review, including the Broadlands River CFMP
- Identifying land at risk of flooding from sources other than rivers and sea
- Review of the flood zones boundaries using newer models built between 2005 and 2007, including the EA catchment modelling of the River Yare (Blackwater) by Babtie, Brown & Root (BBR)
- Re-delineation of Flood Zones 3a and 3b as defined by PPS25
- Updating of the climate change scenario in accordance with PPS25
- Runoff evaluation for areas of large developments

1.2 The Study Area

The extent of Breckland District is shown on Figure 1.1, together with the location of the principal watercourses and reservoirs. The entire district is underlain by chalk and receives very low annual rainfall; average annual amounts varying from 580 to 680mm across the district. The district is essentially rural in nature, with a substantial amount of woodland to the west around Thetford and Swaffham. Elsewhere it is largely heathland or agricultural land.

The EA is responsible for the operation and maintenance of the Main River flood defence assets and for flood warning. The Main Rivers in the west of the area that form part of the River Great Ouse basin are the responsibility of the EA Anglian Region Central Area. The Main Rivers in the Dereham area that cross the district's eastern boundary are the responsibility of the EA Anglian Region Eastern Area. The Main Rivers within the district which impact on the SFRA are:

- River Nar (Central Area)
- River Wissey (Central Area)
- Little Ouse River (Central Area)
- River Thet (Central Area)
- Watton Brook (Central Area)
- Blackwater River (Eastern Area)
- River Tud (Eastern Area)
- River Wensum (Eastern Area)
- Wendling Beck (Eastern Area)

The responsibility for the minor watercourses and flood defence assets lies with different organisations including landowners, Parish Councils, District Council, Anglian Water, and Internal Drainage Boards (IDBs).

There are no Critical Ordinary Watercourses (COWs) identified within the District.

There are two Internal Drainage Boards (IDBs) with responsibilities in Breckland. These are the East Harling and the Norfolk Rivers. The Norfolk Rivers IDB has recently been created through the amalgamation of a number of smaller IDBs within Norfolk. The Norfolk Rivers IDB is itself part of a larger consortium called the King's Lynn Consortium. The Norfolk Rivers and East Harling IDBs both rely on gravity drainage and have no drainage pumping stations. There are no formal flood defences in either IDB area.

There are 25 large raised reservoirs located within the Breckland District, as shown on Figure 1.1. Large raised reservoirs are defined as those capable of holding 25,000 cubic metres above lowest natural ground, and are regulated by the Reservoirs Act 1975. As described in the Development of Flood Plans for Large Raised Reservoirs in England and Wales (Hope, 2007), reservoir undertakers are responsible for ensuring safety, compliance with the law and assessing the flood risk posed by their reservoirs. The EA is responsible for enforcing the Reservoirs Act 1975, by making sure that reservoir undertakers fully comply with the law.

The areas which are proposed in the Local Development Framework (LDF) to possibly accommodate significant growth are:

- Attleborough
- Dereham
- Swaffham

- Thetford
- Watton

These are referred to in this report as the Proposed Growth Areas.

It is of particular significance that in 2006 Central Government identified Thetford as one of 29 National Growth Points which have the potential to provide up to 100,000 new homes in addition to those previously planned, and many new jobs over the next 15 years.

In addition, the District expects that the following larger villages may also accommodate development:

Banham, Great Ellingham, East Harling, Mattishall, Narborough, Necton, North Elmham, Old Buckenham, Saham Toney, Shipdham, Swanton Morley and Weeting.

These are referred to in this report as the Larger Villages.

1.3 Definition of Flood Risk

In accordance with the latest guidance from the EA, the risk of a particular magnitude of event is presented in this report as the percentage likelihood of the event occurring in any one year. Thus a 1% event is that which has a 1% or 0.01 probability of occurring in any one year, and a 0.1% event is that which has a 0.1% or 0.001 probability of occurring in any one year.

The equivalents in terms of "return period" are 1 in 100-year for the 1% event, and 1 in 1000-year for the 0.1% event.

1.4 Project Output

The principal outputs of the project are:

- the mapping of the Proposed Growth Areas and Larger Villages showing land classified to PPS25 Zones as set out in Table 3.2 below,
- the mapping of historical flood events or incidents from all types of sources,
- the estimation of the potential extra runoff from all new large proposed developments which will have to be managed in order to avoid the increase of risk of flooding elsewhere.

The flood zone maps accompanying this report are at 1:10,000 scale and show land classified to the appropriate PPS25 Flood Risk Zone 1, 2, 3a, and 3b. Maps have been produced for the present day (2007), and for 100 years' time (2115) with the impact of climate change on river flows. The maps have been produced digitally with O.S. 1:10,000 scale mapping as a backdrop. There are 25 sheets covering the Proposed Growth Areas and Larger Villages. Hard copy versions of the present day and the 2115 maps have been submitted to accompany this report. A key plan to the map tiles is given as Appendix I and with the final 1:10,000 mapping.

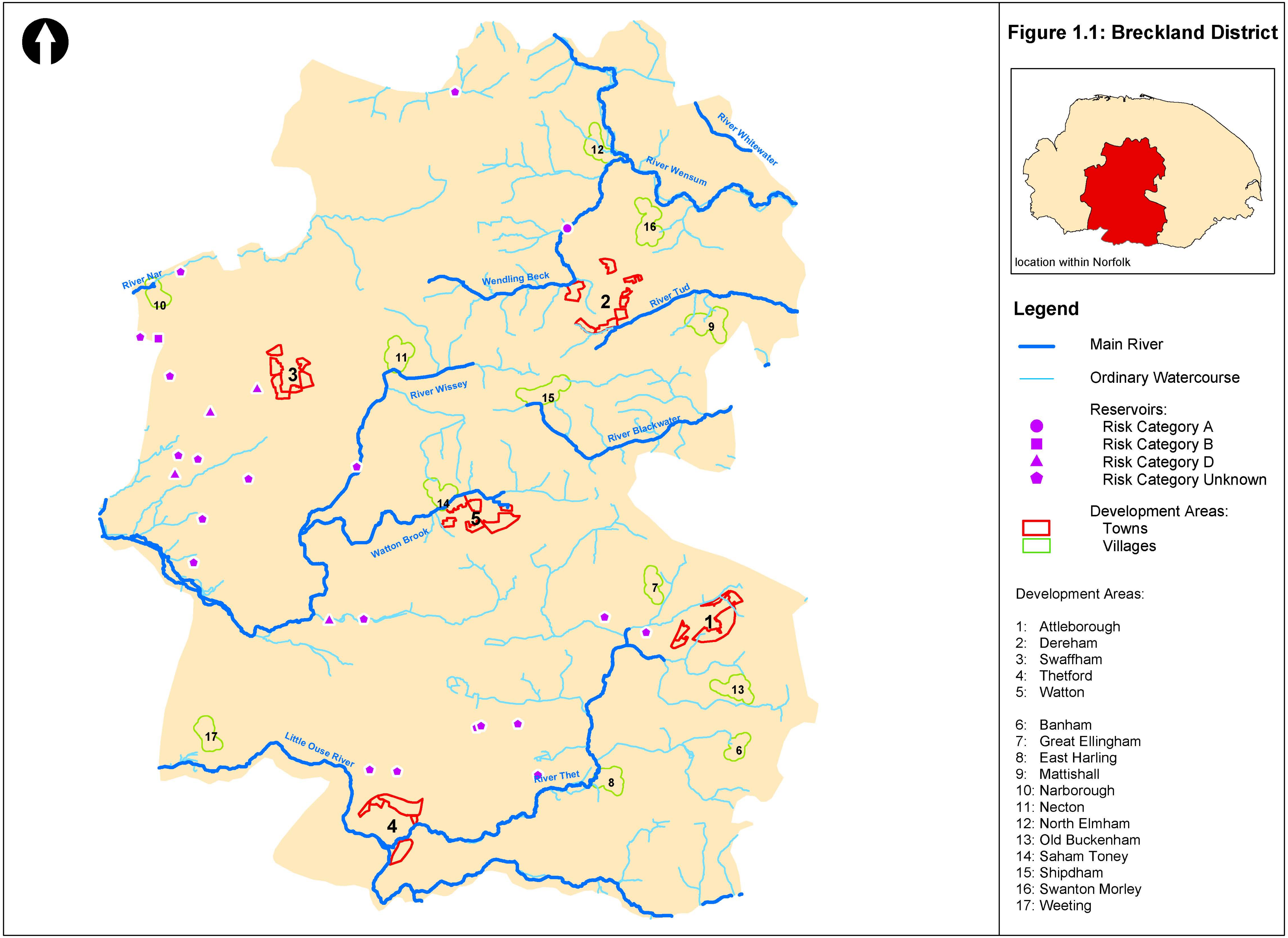
The final maps are also supplied in a GIS format compatible with ESRI GIS, and are attributed to suit the outcome of the study and EA requirements. The maps show O.S. grid co-ordinates and are complete with a legend and title block, to the agreed style.

The Flood Risk Zones are delineated by using colour as agreed with the EA and BDC. Light blue is used to show Zone 3 in areas where new mapping has been developed for the SFRA from either new or existing detailed modelling. Yellow is used for Zone 3 in areas assessed using Level A techniques; and light grey is used where the flood extents have been taken directly from the EA Flood Zone Maps.

Zone 2 is shown as dark grey and has come from the EA Flood Zone Maps. Other layers incorporated in the GIS include the forecast 1% floodline for 2115, which has been added as a dark blue extension to those areas of Zone 3 where new mapping has been developed for the SFRA from either new or existing detailed modelling.

The SFRA outputs should be used in conjunction with the Flood Zone Maps, given that the Flood Zone maps include floodplain assessment on watercourses not covered by the SFRA. The Flood Zone Maps are intended for planning consultation purposes only, and the EA's 'Flood Map' remains the main public dataset. This report accompanies the 1:10,000 scale maps and explains how the SFRA results were obtained.

Figure 1.1: Breckland District



2 Data Collection and Verification

This section describes the data used within the SFRA.

Appendix F and G detail all the data sources relevant to flood risk within Breckland which have been identified as part of this study. This includes historical flooding records, as well as other sources for flood mapping such as terrain data, and hydraulic models.

2.1 Historical Flooding

As part of the SFRA update, there was a need to identify those areas within Breckland District that are liable to flooding from every kind of source, including reservoirs, groundwater, sewers and surface water. Therefore, contacts have been made with the relevant Internal Drainage Boards, EA offices and other organisations, to obtain records of any historical flood events. All this information is included in Appendix F.

2.1.1 The Environment Agency

In 2005, GIS files were obtained from the EA Central Area showing the extents of flooding for 15 flood events between 1937 and 1993.

The EA Eastern Area had no available information on historical flood events at that time.

In 2007, the EA from both Central and Eastern Areas were contacted again and asked to provide two types of information:

- Records of new fluvial flood events since 2004.
- All records of groundwater flooding in the area.
- All records of surface water flooding in the area.

The Central Area had no comments on any events within the Breckland District.

The Eastern Area indicated that surface water flooding occurred in Dereham from 14 to 17 June 2007. There have been four flood watches in their area since 2004 and one flood warning, on 3 March 2007 for the Wendling Beck between Wendling and Worthing, but these do not certify that there was any flooding.

A further contact with the EA was made to obtain any records of flooding due to 'large raised reservoirs' in the district. The EA provided a list of the large reservoirs within the District, including their risk category, which is based on the consequence of breaching. However there have been no records of flooding that can be traced back to the reservoirs as their source or cause.

These data are detailed in Appendix F1.

2.1.2 Flood Studies Reports

As part of the SFRA update, MM collected several flood studies reports for Breckland that have been commissioned by the EA over the past few years:

- Upper River Wensum Strategy Study, completed in 2004 by BBR,

- River Yare Flood Risk Study, completed in 2005 by BBR,
- Thetford Standard of Protection Study, completed in 2006 by Halcrow.

The Thetford Standard of Protection Study identified dates of major floods in Thetford since the 19th century: 9 August 1843, 26 August 1912, January 1915, 1939, 1947, 19 March 1947 and September 1968.

The Upper River Wensum Strategy Study only had two events to be commented on. The first, in August 1912, was the largest known flood event on the river. The second was in October 1993. During this latter event, several properties were flooded in Lyng, Lenwade, Wendling, Scarning, Worthing, and Gressenhall.

None of the flooding events listed in the River Yare Flood Risk Study occurred within the Breckland District.

These data are detailed in Appendix F1.

2.1.3 Breckland Council

In 2005, Breckland District Council provided a report on flooding in the towns and villages of the district. This did not give any specific information as to dates of recent flood events.

In 2007, the Breckland Council Planning Policy Officer and Amenity Services Manager were contacted to obtain any records of flooding since 2005. A list of eight events of flooding to properties was supplied, all of which were due to maintenance issues such as blocked drains or infilled ditches. Further to this, a record of all sandbag deliveries made to properties in the district since 2005 was supplied.

These data are detailed in Appendix F2.

2.1.4 Internal Drainage Boards Data

In 2005 both King's Lynn Consortium of IDBs and East Harling IDB were contacted for information on any flood events from ordinary watercourses. King's Lynn Consortium of IDBs did not hold flood event records. East Harling IDB stated that there is regular flooding of the water meadows along the Attleborough watercourse and the River Thet at Larling, but that this has no impact on buildings. King's Lynn Consortium of IDBs provided an AutoCad file showing the location of the drains under their jurisdiction.

In 2007, none of the IDBs had any additional information to provide regarding flood events between 2005 and 2007.

2.1.5 Anglian Water

During the SFRA 2007 update, Anglian Water provided information on sewer flooding, from both surface water and foul sources, from 1998 to 2006. These data are detailed in Appendix F3.

2.1.6 Highways Agency

The Highways Agency provided data on callouts to trunk roads A11 and A47 in the Breckland District during flood events. These data are detailed in Appendix F4.

2.1.7 Online Newspaper "Lynn News"

As Part of the SFRA update, MM searched in the Lynn News online archive for flood events in the Breckland District. Three relevant articles were identified and have been included in Appendix F. The following information was extracted from these articles.

The Swaffham Town Mayor told the Lynn News in September 2002 that he had been complaining about flooding in the Sporle Road, New Sporle Road and West Acre Road areas after heavy rain for the past 30 years. He stated: 'We get raw sewage coming up and that creates a health problem because in hot weather there are children paddling in the floodwater.'

Road flooding was reported on 17 July 2003 in Weeting, but does not seem to have been particularly significant.

It was reported on 29 June 2007 that sewage polluted flood water was threatening bungalows in Chantry Lane, Chantry Court and Mill Street in Necton following a torrential rain. Flooding seems to have originated from several sources: surface water flooding due to some blocked drains, fluvial flooding due to a blocked culvert of the Necton Brook in Chantry Lane, and sewer flooding due to a manhole cover being lifted in Chantry Lane. A resident who lived in Chantry Lane from 1967 to 1997 was quoted as saying that: 'during exceptional and prolonged storms the culvert could not cope with the excess amount of surface water from the new housing estates, and flooding resulted.'

2.2 Data Sources for Fluvial Modelling and Mapping

2.2.1 Hydraulic Modelling and Channel Survey

The principal sources of data for the Main River flood extents are the various numerical modelling studies and flood mapping exercises which have been carried out over the last few years for the EA by a number of consultants. In addition, Dereham Stream, an IDB ordinary watercourse, has been modelled for King's Lynn Consortium of Internal Drainage Boards. The existing hydraulic models utilised in the study are summarised in Table 2.2. Mott MacDonald also built several models for the 2005 study where modelling work had not previously been undertaken and where channel survey was available.

Table 2.1: Hydraulic Models Used for the SFRA

Watercourse	Reach covered	Report Date	Report Authors	Client	Software
River Thet and River Little Ouse	Thetford	2006	Halcrow	EA	iSIS
Upper Yare	From Shipdham to western outskirts of Norwich	2005	Babtie, Brown and Root	EA	iSIS
River Tud	From Dereham to confluence with the River Yare	2005	Jeremy Benn Associates	EA	iSIS
River Thet	East Harling	2005	Mott MacDonald	Breckland Council	iSIS
Watton brook	Watton	2005	Mott MacDonald	Breckland Council	iSIS
River Wissey	Necton	2005	Mott MacDonald	Breckland Council	iSIS
River Wensum	River Tat confluence to	2003	Babtie,	EA	iSIS

	Costessey Mill, tributaries Wendling Beck and Whitewater.		Brown and Root		
Dereham Stream	Norwich Rd, Dereham to Wendling Brook confluence.	1991	Mott MacDonald	King's Lynn Consortium	HYDRO-1D

The Wensum, Yare, Tud, Thet and Little Ouse model reports were received from the EA. Since these models have been developed for the purpose of flood risk mapping they were considered to be appropriate for use in this study. The data received included water levels and flood outlines for some of the required return periods. More details are provided in Appendix G.

The Dereham Stream model was created by Mott MacDonald for King's Lynn Consortium of IDBs to investigate channel capacity. Hydrological analysis was originally performed using Flood Studies Report (FSR) methods. For this current study this has been updated to use methods from the Flood Estimation Handbook (FEH). This process is described in more detail in Appendix D.

The models for the River Thet at East Harling, Watton Brook at Watton and the River Wissey at Necton were built by Mott MacDonald in 2005 specifically for the Breckland SFRA, using survey data provided by the EA. This survey data was of varying quality and age, and variously available in digital or hard copy format. The availability of this data is detailed in Appendix G. These models are described in Appendix D.

It should be noted that the 2007 Breckland SFRA has been updated with newer models which supersede some of the models which had been used in 2005. Details are given in Table 2.2.

Table 2.2: Superseded fluvial models

Model used in 2005 SFRA	Newer model used in 2007 SFRA
River Tud at Dereham (MM, 2005)	River Tud (JBA for BBR, 2005)
River Tud at Mattishall (MM, 2005)	River Tud (JBA for BBR, 2005)
River Blackwater at Shipdham (MM, 2005)	Upper Yare (BBR, 2005)
River Thet and River Little Ouse for 2 km upstream and 1 km downstream of Thetford (PH, 2000)	River Thet and River Little Ouse covering Thetford entirely (Halcrow, 2006)

2.2.2 Terrain Data

In any flood risk assessment exercise the availability of reliable ground level data is of vital importance. There are various forms of terrain data available for the study areas. LiDAR is currently the most accurate source of terrain data available for large areas such as Breckland. The LiDAR sensor provides a very dense sample of ground levels, which are then converted into a grid. The resolution of these grids is determined by the density of the samples, in general 2 m. Taken together with the accepted vertical accuracy of ±15 cm, this indicates that in the areas covered, the LiDAR data provides a good representation of ground surface for the required flood zone mapping. The studied areas are covered by 188 LiDAR 2 km by 2 km tiles shown in Figure G.1. The availability of LiDAR is shown in Table 2.1 below.

IFSAR (Interferometric Synthetic Aperture Radar) data from NEXTMAP has also been obtained from the EA. This covers the entire study area and was utilised where LiDAR is unavailable. The vertical accuracy of this data is generally accepted as ±70 cm. SAR and LiDAR data were compared over the district area and it was decided to apply an adjustment of -0.4 m to the SAR data to obtain the best match to the LiDAR data.

Table 2.3: Coverage of LiDAR Data

Proposed Development Area/ Larger Villages	**Percentage LiDAR Coverage**
Attleborough	5
Dereham	90
Swaffham	0
Thetford	100
Watton	95
Banham	0
Great Ellingham	0
East Harling	0
Mattishall	100
Narborough	0
Necton	5
North Elmham	100
Old Buckenham	0
Saham Toney	100
Shipdham	100
Swanton Morley	100
Weeting	100

2.2.3 Interface with Environment Agency Flood Risk Products

It is recognised that this SFRA is being carried out at a time when a number of other flood risk products are under development. The EA has replaced its Indicative Flood Map (IFM), which had been in use for five years, with a range of new products covering England and Wales. Of these products the Flood Zone Maps are of particular relevance to the SFRA work since they show flood risk in terms of the PPS25 Flood Zones, as defined in Table 3.2 below. The Flood Zones shown on the EA maps correspond to those defined as Zone 2 (Medium Probability) and Zone 3 (High Probability and functional floodplain) in PPS25. The principal difference between the EA Flood Zone maps and the SFRA maps is that the EA Flood Zone Maps do not show the outline for Flood Zone 3b, corresponding to the functional floodplain. It is important to note that both the EA and PPS25 Flood Zones refer to the probability of river or sea flooding ignoring the presence of defences.

In addition, there will be differences arising from the various methods used to derive the zone boundaries. The SFRA uses results from detailed hydrological and hydraulic modelling of all Main Rivers to obtain flood levels, and combines these with ground level information predominantly sourced from LiDAR techniques giving a vertical accuracy of +/- 15cm. For non-Main Rivers in areas of particular concern, the SFRA flood extents have been derived from detailed site investigations.

For the EA Flood Zone maps, the basic zoning has been based on a relatively coarse national hydrological model combined with a new national DTM sourced from IFSAR techniques, giving a vertical accuracy of +/- 70cm. However, where better modelling is available, the EA have included the outputs in the Zone 3 extent, in many cases this is the same modelling as has been used in the SFRA, and therefore the outputs should be similar.

2.2.4 River Gauging Station Data

Gauging station data was utilised to undertake hydrological analysis to determine the design inflows to the hydraulic modelling. The use of this data is described in Appendix D.

2.3 Broadlands Rivers CFMP

The Broadlands Rivers Catchment Flood Management Plan (CFMP) was provided by the EA.

The CFMP area is composed of six main catchments, of which two partially fall within the Breckland District:

- The River Upper Yare
- The River Wensum and its tributaries, including the River Tud.

The report summarises the geology of the CFMP area as chalk and clays, covered with glacial deposits of sand, silt and clay. However, there are some outcrops of chalk in the upper river catchments in the north of the area. There are many major aquifers contained within the chalk geology of the CFMP area. Groundwater generally flows east. The soil in the catchments of the Upper Wensum and the Yare is stated as being mostly ‘deep coarse and fine loam’ and ‘wet deep loam to clay’.

The Upper Wensum, Upper Yare and the River Tud were analysed for their response to previous flood events, which was generally found to be slow due to their partially permeable catchments. However, in steeper areas of the upper catchments of the rivers Yare and Wensum, flooding may be flashy, caused by quick runoff to rivers following short heavy rainfall, which can pose a greater risk to life as there is less time for response.

The CFMP highlights the characteristics of the main sources of flooding. Tidal flooding does not affect the parts of the Wensum and Yare catchments upstream of Norwich, and therefore does not affect Breckland District. It is also stated that fluvial flooding from rainfall and melting snow dominates the upper parts of the rivers Yare and Wensum. It highlights the reliance of some settlements, in particular East Dereham, on Internal Drainage Boards’ pumps and maintenance for protection from localised flooding. Generally the standard of defence for IDB drainage in developed areas is one in 25 years.

Localised surface water flooding is identified as particularly problematic in two types of area relevant to this SFRA – steep upper catchments and urban areas with low permeability. Sewer flooding can also be a local problem in urban areas. Groundwater flooding could potentially be an issue where there are outcrops of chalk geology, but this is not reported to be an issue in the CFMP area.

2.4 Sewage Works

The EA has supplied information on the location and magnitude of permitted discharges from existing sewage works serving the development areas. This data has been utilised to assess the flood risk implications of the potential increased discharges from the works to watercourses due to the proposed developments. This analysis is presented in Appendix F. It should be noted that of the total of 96 outfalls within Breckland District, there are consents for daily maximum volumes of discharge at only 15 sites. Although the SFRA is able to give general guidance on the likely impact of increased discharges, the detailed impact of any increased discharge on a receiving watercourse will need to be assessed at a later stage of the planning process, taking into account the nature and size of specific proposals for development.

Some of these impacts could be highly significant given the magnitude of forecast growth in some areas and the relatively small size of the receiving watercourses, particularly at Dereham and Attleborough, where sewage works are struggling to met their consented effluent quality standards.

River quality issues were not included in the scope of this SFRA, but can be analysed as part of Water Cycle Strategies (WCS). A WCS is being carried out for Thetford. Breckland Council are aware that it might become necessary to carry out WCS for Attleborough and Dereham as well.

3 Assessment of the Flood Risk

3.1 Sources of Flooding

All the historical flood data described in Section 2.6 have been plotted together on the map shown as Figure 3.1, in order to provide a tool for determining the main sources of flooding within Breckland. The sources of flooding have been classified according to the PPS25 Companion Guide, Chapter 2. Fluvial flooding, surface water flooding, sewer flooding and flooding due to infrastructure failure (such as a blocked culvert) have all been found to be significant. There is no evidence of tidal, groundwater, or reservoir sourced flooding.

3.1.1 Fluvial

Fluvial flood extents provided by the EA show flooding on the River Thet at Thetford and East Harling in 1947 and 1968. East Harling IDB reported that the River Thet is regularly flooding at Larling, to the north of East Harling.

Fluvial flood extents from the EA also show flooding along the River Little Ouse in 1947 and 1968 and on the River Wissey in 1947.

According to the Upper River Wensum Strategy Study, the worst flood event on the Upper Wensum was in August 1912, and several properties were flooded in Lyng and Lenwade in October 1993. The report also states that Wendling Beck flooded between Wendling and Worthing in October 1993, including Dereham and Gressenhall. The EA records show that there has been one flood warning in June 2007 and four flood watches since 2004 along this portion of the river.

According to the Breckland District Council records and the Lynn News, Necton Brook has flooded many times in Necton, Chantry Lane, affecting several properties, due to a blocked/undersized culvert.

There is some history of fluvial flooding in Attleborough from the Besthorpe Stream, the Attleborough Stream, and surrounding ditches. A resident explained that Besthorpe Stream flooded some properties in 1997-1998 due to blockages of the trash screen of the culvert under Mill Lane. According to Breckland District Council records, Attleborough Stream flooded several times due to capacity issues, in particular of the culvert under Norwich Road. Houses on the Norwich Road have been flooded up to a depth of 3 ft. Ditches have also been reported to be blocked. East Harling IDB reported that the water meadows along the Attleborough Stream are regularly flooded.

According to the Breckland District Council records, the Dereham Stream has numerous localised flooding events affecting properties in Toftwood and Swanton Road areas.

3.1.2 Tidal

Of the settlements being studied, only Narborough was considered to be under any risk of being affected by sea level rise. However, the outfall from the River Nar into the River Great Ouse is protected by a gated structure. This means that the River Nar is not directly affected by the tide.

We have consulted Royal Haskoning (RH), who have completed a modelling study of the River Nar upstream as far as Marham (downstream of the Breckland District). They have confirmed that even with a major tidal event on the Great Ouse coincident with a fluvial event on the Nar causing it to backup behind the tidal outfall structure, water levels would not be affected as far upstream as Marham, due to the nature of the river gradient.

3.1.3 Infrastructure failure

According to the PPS25 Companion Guide, infrastructure failure includes:

- Reservoirs
- Canals
- Industrial processes
- Burst water mains
- Blocked sewers or failed pumping stations

In addition to the types of infrastructure failures listed in the PPS25 companion guide, it was assumed that blocked culverts, highway gullies, drains and pipes were included in the infrastructure failure category.

There is no record of reservoirs flooding in Breckland. However each reservoir is attributed a risk category (Figure 1.1), which is based on the consequence of flooding, as shown in Table 3.1. In Breckland there is only one reservoir classified in the highest risk category “A”, Dillington Carr, located in the north-west of Dereham. There is also one reservoir classified in the category “B”, Hanger End, near Narborough. All the other reservoirs are classified in lowest risk category “D”, or the risk has not been assessed.

Table 3.1: Consequence classification for impounding reservoirs

Risk Category	Notes (Floods and Reservoir Safety; ICE 1996)
A	At least 10 lives at risk and extensive property damage
B	Fewer than 10 lives at risk but extensive property damage
C	Negligible risk to human life but property damage
D	No significant risk to life or property damage

The Highways Agency records show that the A11 and/or the underpass at Stone Cross, near Roudham Heath, have been flooded several times since 2002 due to pumping failure. Blocked gullies have been the cause of surface water flooding on the A47 in July 2004 near Dereham, and July 2005 between Little Fransham and Scarning, and on the A11 to the north-east of Thetford in August 2006.

Surface water flooding occurred in Necton in the area of Chantry Lane due to blocked drains (Lynn News, June 2007). Blocked ditches contributed to floods in the Besthorpe area in Attleborough.

As highlighted in the Broadlands River CFMP, East Dereham is heavily reliant on maintenance and pumping. Records from Breckland Council show that it has been flooded in St George Drive due to a blocked pipe, and in a garden in Larners Drift, Toftwood, due to undersized pipes under the garage.

3.1.4 Surface Water

Surface water flooding is defined in the PPS25 Companion Guide as sheet run-off from adjacent land, urban or rural. For practical purposes, MM decided to include ditches and drains in this category.

In Breckland this mostly consists of localised road flooding after intense rainfall when the water is unable to drain quickly enough. Several incidents have been reported on the A11 and A47; in particular the A11 at Attleborough and Thetford seems to be affected, as well as the A47 at Swaffham and Dereham. Road flooding was also reported in Weeting in July 2003 (Lynn News, 2003).

In addition surface water flooding has been reported in several settlements. Long Street in Great Ellingham is prone to surface water flooding due to the lack of maintenance and/or lack of capacity of the ditch. There is a surface water drainage issue in Swaffham, in particular in Northwell Road. Dereham has been flooded by surface water in June 2007.

There are some ditch capacity issues in the area of Besthorpe, near Attleborough, and sandbags have been delivered on several occasions.

3.1.5 Groundwater

Owing to the underlying chalk aquifer in the district, groundwater flooding could potentially be an issue but no flood event has been reported.

3.1.6 Sewers

According to the PPS25 Companion Guide, sewer flooding includes combined, foul or surface water flooding. Sewer flooding happens when the sewer is full and overflows occur outside of the building at manholes or drains in gardens (known as external flooding); or even inside of the building from toilets and drains (called internal flooding). It is also called internal flooding where a building has suffered flooding both outside and inside. Basement conversions are particularly prone to sewer flooding, where they lie low relative to the depth of the public sewer.

The Lynn News reported that sewer flooding occurred in Necton, Chantry Lane, in June 2007 due to a manhole cover being lifted up. The Lynn News also reports regular sewer flooding in Sporle Road, New Sporle Road and West Acre Road, in Swaffham.

Anglian Water reported several sewer flooding incidents in Breckland, mostly external, with frequencies between 2 every 10 years (2:10) and 1 every 20 years (1:20).

Dereham is the county “hotspot” for sewer flooding, which has occurred at the following locations: Norwich Road, South Green, Swanton Grove, Swanton Road, Wellington Road, Larner’s Drift, Rash’s Green, Hillcrest Avenue, and Boyd Avenue. Particularly noticeable are the internal flooding at Larner’s Drift and the external flooding at Norwich Road which both occur at the high frequency of 2:10.

According to the Environment Agency, sewer flooding in Larner’s Drift and Lavender Grove occurred in a number of recent years due the unauthorised connection of surface water drainage facilities into the foul sewer.

Sewer flooding is also quite significant in Watton in Brandon Road, Swaffham Road, Saham Road, and particularly in Norwich Road with 2:10 years frequency (internal and external).

Internal and external sewer flooding occurred in Thetford town centre at Bridges Walk in August 2006 with 1:20 frequency and to the north of the town in Fairfields with 2:10 frequency.

There is a sewer flooding issue in Bell Lane in Saham Toney, with a flooding frequency 1:10.

Internal sewer flooding occurs in Chapel Street in Shipdham with 2:10 frequency.

In addition sewer flooding has also been recorded in Bawdeswell and Whissonsett, where development is not expected.

Figure 3.1: Breckland Flood History Map

3.2 Determination of the Fluvial Flood Zones

3.2.1 Flood Zones Definition

The SFRA requires that Flood Risk Zones are defined in accordance with the criteria set out in PPS25. For land at risk from fluvial flooding, these criteria require differentiation according to the following "sequential characterisation of flood risk":

Table 3.2: Flood Risk Zones in PPS 25

Flood Zone	Annual Probability of flooding	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
1	LOW < 0.1%	√	√	√	√	√
2	MEDIUM 0.1 - 1.0%	√	√	Exception Test	√	√
3a	HIGH > 1.0%	Exception Test	√	X	Exception Test	√
3b	Functional floodplains. > 5.0%	Exception Test	√	X	X	X

* For full details see Tables D1, D2 and D3 of PPS25.

3.2.2 Flood Zones Boundaries

- Zone 1 / Zone 2 Boundary

The principal criterion for differentiation between the PPS25 Zones 1 and 2 is the 0.1% (1000-year) event.

The 0.1% (1000-year) extreme flood outline for the Strategic Flood Maps has been taken from the same source as the EA Flood Zones. This is important since the Agency emphasise the need for outputs of SFRAs to be compatible as far as possible with their latest flood mapping products. Since the extreme flood outline forms an important part of the Agency's new Flood Risk Mapping Strategy, there was a very strong case for its use in the SFRA.

The 0.1% outlines shown on the final 2007 SFRA maps take account of modifications carried out by the EA whereby all substantiated historic flood information held by the Agency has been included.

- Zone 2 / Zone 3 Boundary

The principal criterion for differentiation between the PPS25 Zones 2 and 3 is the 1% (100-year) event. The 1% flood extent outline for the Strategic Flood Maps has been obtained in accordance with the processes set out in Section 3.4 below.

- Zone 3b – Functional Floodplain

During the first stages of this study in 2005, the functional floodplain had been defined by the extent of the 10% (1 in 10-year) flood outline. As part of the SFRA update in order to comply with PPS25, it has been agreed with the EA to redefine the functional floodplain by the extent of the 5% (1 in 20-year) flood outline. For Main Rivers this flood outline has been obtained using similar procedures as for the 1% outline.

3.2.3 General Methods for Determining the Flood Zones

In order to differentiate between Flood Zones 1, 2 and 3 the 0.1% and 1.0% flood outlines were plotted. In addition Flood Zone 3b was defined by plotting the 5% flood outline. As noted above, the 0.1% outline was taken from the EA Flood Zone Maps. The 1% and 5% outlines were determined for each area as noted below.

Appendix A details the Flood Zones for each Proposed Development Area and Appendix B documents the Larger Villages. Both appendices describe the methodology specific to each site for delineating the flood zones and outline the flood risk in each settlement.

(i) Reaches with Existing Modelling

Prior to this study there has been limited modelling undertaken along the rivers affecting the Proposed Development Areas. However, where this has been undertaken it has generally been prepared for the EA. As part of the work undertaken for the SFRA the 1% and 5% flood outlines have been produced by extracting from hydraulic models the 1% and 5% water levels at regular intervals along the rivers. Ground level contours have been created using LiDAR data supplemented as necessary by SAR data, local site surveys and/or OS data. The levels obtained from the models have been projected onto the floodplain until the flood levels meet the ground level contours at the section. The intersection points have then been joined to form the flood outlines.

The original modelling on Dereham Stream did not produce flood outlines; however these have now been produced using the available terrain data.

The hydrological inputs to the Dereham Stream model were originally produced using the Flood Studies Report (FSR) methodology. This method has since been superseded by the Flood Estimation Handbook (FEH) and the impact of this updated hydrology upon flows in the catchments has been assessed. This is detailed in Appendix D.

(ii) Reaches with Cross Section Survey but no Existing Modelling

Cross section survey data exists for many of the Main Rivers and some lengths of ordinary watercourse in Breckland. Where such survey is available in or adjacent to the Proposed Development Areas or Larger Villages, it has been used to construct a hydraulic model. As part of the SFRA Stage 2 work (2005) six such hydraulic models have been constructed:

Table 3.3: Hydraulic Models Constructed Specifically for the SFRA

River	Proposed Development Areas / Larger Villages	Approximate Length (km)
River Tud	Dereham	2.5
Watton Brook	Watton, Saham Toney	5
River Tud	Mattishall	4.5
River Wissey	Necton	3
River Blackwater	Shipdham	1.5
River Thet	East Harling	3

The River Tud at Dereham, the River Tud at Mattishall, and the River Blackwater at Shipdham models have since been superseded by newer models of the River Tud and River Yare, as described in Section 2.2.

For the Watton Brook at Watton, River Wissey at Necton, and River Thet at East Harling models, the 1% and 5% flood outlines were produced as follows:

- derivation of the 1% and 5% flow from FEH procedures
- use of available channel cross section data to set-up a steady-state hydraulic model using iSIS software
- use of the model to determine peak flood levels for the design events
- production of a ground surface model using LiDAR or other available terrain data
- projection of the peak flood levels onto the ground surface model to determine flood extents.

The hydraulic models produced are documented in Appendix D.

(iii) Reaches without Cross Section Survey

Site visits were undertaken for the sites with no cross section survey. The length of each watercourse was walked by an experienced engineer who made use of all the available information to plot indicative flood extents for the 1% event. This assessment made use of engineering judgement, catchment details and any historical information. Standards of protection in residential areas affected by the watercourses were also assessed. A total of 31.4 km of ordinary watercourse has been mapped in this way. The lengths studied have been prioritised on the Proposed Development Areas, with the remainder being in the Larger Villages.

This technique of assessment is referred to as Level A mapping, and was developed by Mott MacDonald in conjunction with South West Region of the EA where it has been used to assess the flood risk from over 2000km of ordinary watercourses. The output from JFLOW modelling which forms the basis of the EA flood zone maps, is taken into account in the Level A assessment. However it is noted that JFLOW does not take account of any man-made embankments or of structures which may have a significant impact on the real risk of flooding, particularly for smaller watercourses. Catchments smaller than $3km^2$ generally do not have JFLOW or any other form of existing flood outline. The Level A assessment also uses data from FEH to give an indication of the magnitude of the 1% event, which when used together with the observed channel dimensions, gives a fair degree of confidence to the predictions of the flood outlines.

The outlines produced from the Level A work take account of the estimated backing-up behind structures which would restrict 1% flows, but do not assume any specific blockages. As part of their site visits, MM have assessed the likelihood of blockages. Potential blockages are described in Appendices A and B, and summarised in Table 3.4. It will be the role of flood risk assessments at a site level to assess the consequences of blockage to specific proposed developments

(iv) Internal Drainage Board Areas

The watercourses controlled by the IDBs in Breckland District are all gravity drained. Therefore, flooding is dependent on channel capacity being exceeded. Flood risk from IDB drains in the study area has been investigated through site visits, as described above in Section 3.4.3. The exception is Dereham Stream for which detailed modelling has been carried out, see Appendix D.

Table 3.4: Watercourses prone to blockages in Breckland

Watercourse	Location	Structure / Cause	History of flooding
Besthorpe Stream	Attleborough Site 1 (South East of Railway)	Mill Lane culvert with trash screen	Few properties
Besthorpe Stream	Attleborough Site 1 (South East of Railway)	Norwich Road culvert	yes
Fowler's Lane Drain	Attleborough Site 4 (Haverscroft Street)	Railway culvert	Unknown
OW3 ordinary watercourse	Dereham Site 1 (Swanton Road)	Farm track culvert	Unknown
Neatherd Moor Drains	Dereham Site 3 (Norwich Road)	culvert downstream of Farm Rose	Blocked culvert at the time of the site visit
Neatherd Moor Drains - larger drain	Dereham Site 3 (Norwich Road)	Channel with irregular bed level	Blockages at the time of the site visit
Toftwood Drain	Dereham Site 5 (Toftwood)	Junction with River Tud	Blockage at the time of the site visit
Channel 3 in Neaton	Watton Site 2 (Neaton)	Channel with dense vegetation and sharp bends	Blocked at the time of the site visit
Church Farm Stream	Banham	Series of culverts	Unknown
Mauley's Drain	East Harling	West Harling Road 1 m culvert	Unknown
Forest Lodge Drain	East Harling	No outlet (connection to Maulay's drain has probably been removed)	Unknown
Moat Stream	Mattishall	Dereham Road bridge with limited opening	Unknown
Occupation Road Drain	Mattishall	0.3 m diameter piped culverts to allow access to houses and fields	Water has recently spilled out of the drain, onto the road and into their front gardens.
Butlers Drain	Narborough	0.5 m culvert under Meadow Track in forested area	Channel blockage due to tree branches at the time of the study, with water backing up to the Meadow Lane culvert.
Allotment Drain	Narborough	Culvert under farm access track	Unknown
Town Beck	North Elmham	Footbridge 100 m downstream of Holt Road. Assorted materials fixed by the farmer to the underside of the bridge to contain the animals.	Unknown
Town Beck	North Elmham	Two 0.25 m diameter pipes under Old Hall Farm track	Unknown
Parkland Stream	Shipdham	0.8 m diameter culvert in wooded area with old trash screen lying in the channel	Unknown
Weeting watercourse	Weeting	Brandon Road culvert Poor stream condition	Unknown
Necton Brook	Necton	Chantry Lane culvert	Frequent floods

4 Additional Considerations

4.1 Assessment of the potential increase of runoff due to development

As explained in Section F3 of PPS25, the effect of development is generally to reduce the permeability of the site and its response to rainfall. Without specific measures, the volume of water that runs off the site and the peak run-off flow rate are likely to increase. Inadequate surface water drainage arrangements in a new development can threaten the development itself and increase the risk of flooding to others.

PPS25 therefore requires that the surface water drainage arrangements for any development site should be such that the volumes and peak flow rates of surface water leaving a developed site are no greater than the rates prior to the proposed development. For new development, it may be necessary to provide surface water storage and infiltration to limit and reduce both the peak rate of discharge from the site and the total volume discharged from the site.

According to the Preliminary Rainfall Runoff Management for Developments guidance (EA, June 2007), two kinds of storage should be considered when assessing the flood risk:

- the attenuation storage, which aims to limit the peak rate of runoff from the development to the receiving watercourse to the corresponding greenfield runoff rate,

- the long-term storage, which aims specifically to address the additional volume of runoff caused by the development. It allows the volume equal to the greenfield runoff to discharge at greenfield rate, while retaining the rest of the runoff to discharge as infiltration, or if this is not feasible due to soil type, discharged from the site at flow rates below 2 l/s/ha.

It should be noted that providing attenuation storage only is not sufficient. Without any long term storage, the capacity of a receiving channel is reduced for a long time following a significant rainfall event, due to large volumes of runoff being discharged at the greenfield rate. This leads to an increased frequency of low level nuisance flooding in adjacent residential areas.

It is not the purpose of the SFRA to generate precise storage volume values for each proposed development site. However the initial assessment and comparison of the peak runoff rates and long-term storage volumes required for the different proposed development sites provides an additional tool for the allocation process. These estimates should be refined as part of site specific FRAs, and the attenuation storage volume should also be derived.

The methodology described in the SUDS Manual (CIRIA C697, 2007) was used to estimate the runoff rates and volumes from the greenfield sites and the proposed development sites. MM used the following data provided by the Council for each proposed development:

- Type, residential or employment
- Location
- Range of possible densities
- Range of possible sizes

The types and locations of the proposed developments are shown on the maps included in Appendices A and B. As the densities and sizes of the development sites have not been accurately determined yet, MM has estimated runoff rates and volumes for a range of development densities and sizes.

Regulatory authorities normally require the **developed rate of runoff** to be not greater than the greenfield runoff rate for a range of annual flow rates probabilities up to 1% probability flow. MM estimated the rate of runoff for the 100% and the 1% probabilities events. Additional flow rate probabilities should be considered when producing surface water strategies. The **runoff volume** has been estimated on the basis of the 100 year, 6 hour rainfall event, which is as recommended in Preliminary Rainfall Runoff Management guidance and in the SUDS Manual.

As required by PPS25, climate change impacts on the runoff have been assessed. Due to the current uncertainty with regards to the type of development and its associated lifetime, it was agreed with Breckland District that two climate change scenarios for the runoff rate would be considered:

- From 2055 to 2085: +20% in the peak rainfall intensity
- From 2085 to 2115: +30% in the peak rainfall intensity

Calculations are detailed in Appendix E.

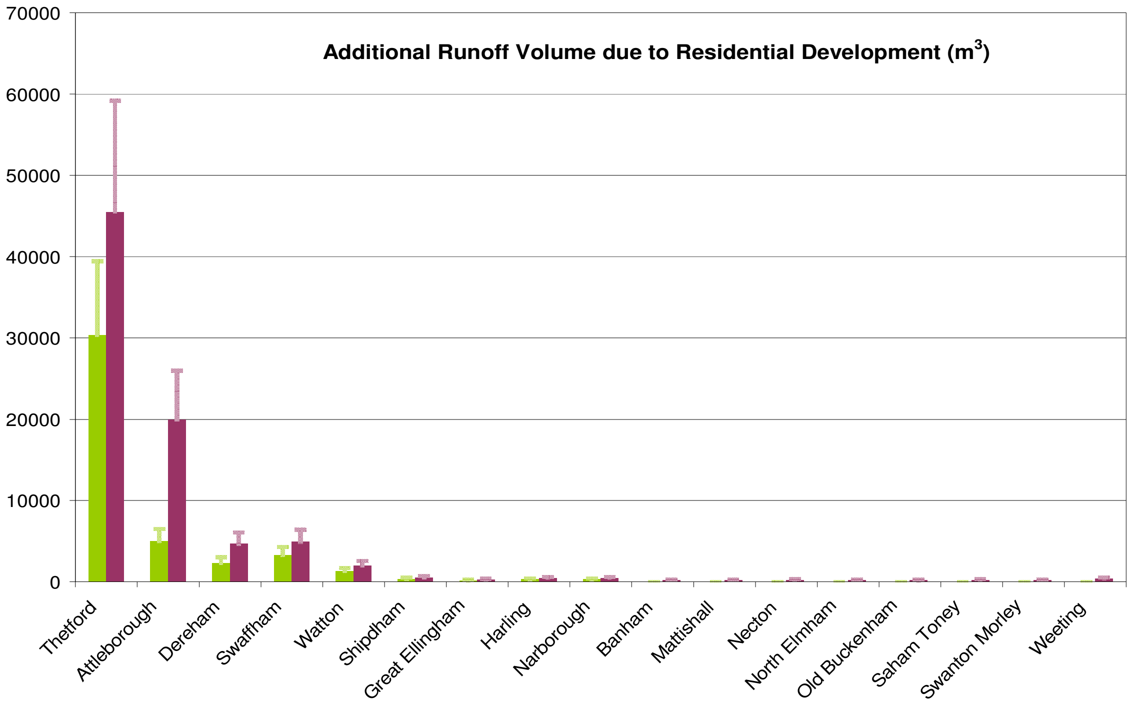
Figure 4.1 and 4.2 show the additional runoff volume generated by the proposed developments for a 1% probability event, 6 hour storm duration, which is also called the “long-term storage”.

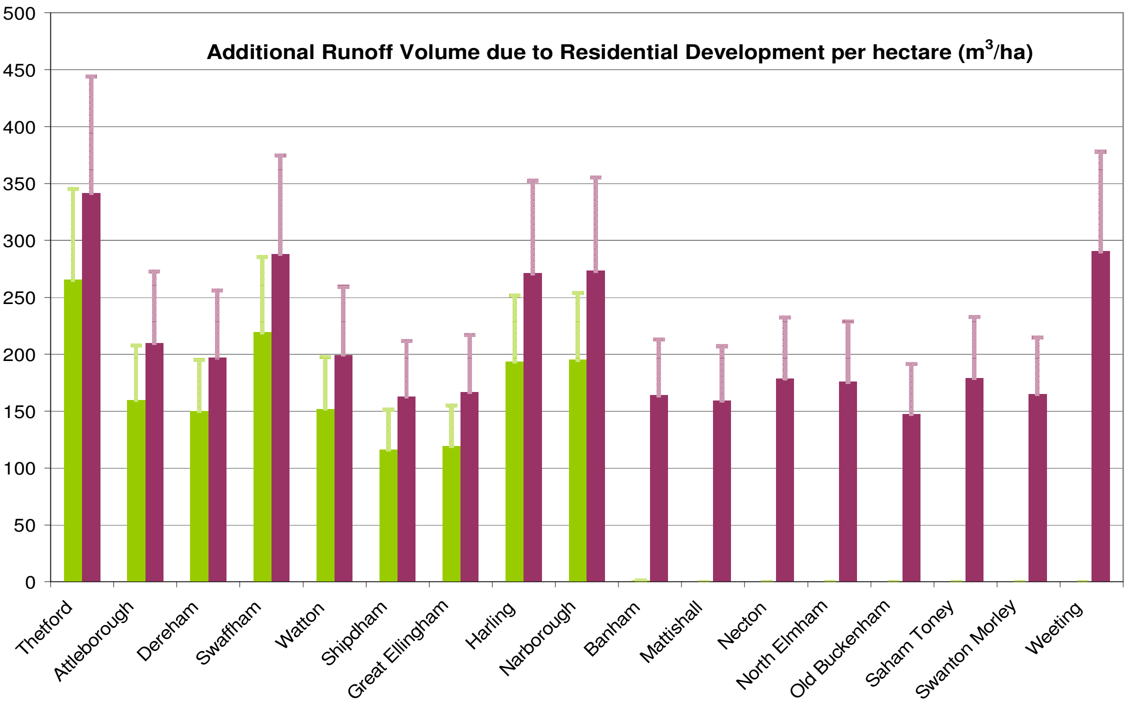
The additional runoff volume per hectare is quite high for all proposed development sites, and particularly in Thetford, Swaffham, Harling, Narborough and Weeting. This is because of the nature of their soils which are very permeable. Most of the rainfall is infiltrated through the ground and very little runoff is produced. The introduction of impermeable surfaces associated with the developments of these sites would disable the natural infiltration process. This should be compensated for with the use of SUDS to re-enable infiltration.

Figures 4.3 and 4.4 show the peak runoff from the proposed development sites and their greenfield equivalents for a 1% probability event. Peak runoff estimates from the residential developments in Thetford and Attleborough appear to be extremely high. Maximum peak runoff values are 45 and 35 m^3/s respectively, corresponding to the maximum housing density and houses number scenario and including the impact of climate change up to 2115. These values are conservative, as it has been assumed that the peak runoffs from the different development areas in Thetford or Attleborough would occur exactly at the same time.

There are documented problems with the capacity of the Dereham Stream and the foul sewerage in Dereham. It is particularly important to provide sufficient attenuation and long term storage in this area. Otherwise there may be an increase in flood risk to existing development close to drainage pathways.

Table 4.1: Additional Runoff Volume due to Residential Development for 1% probability event, 6 hr storm duration





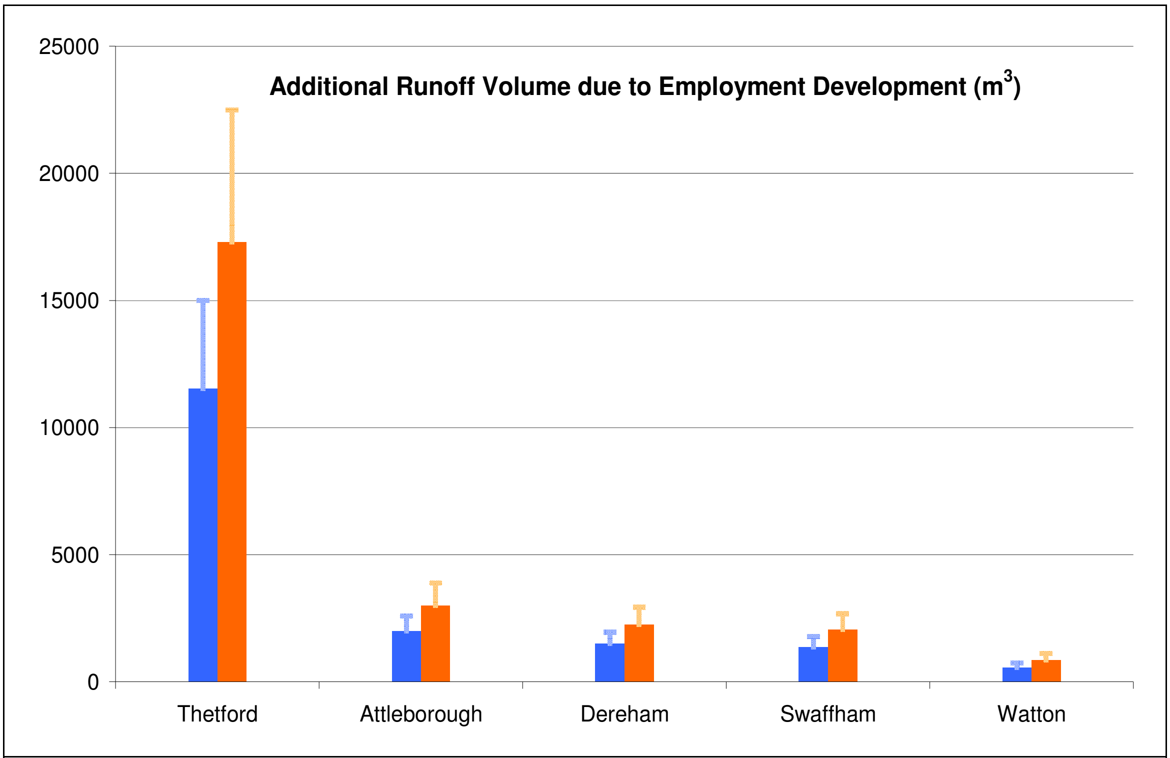
Legend:

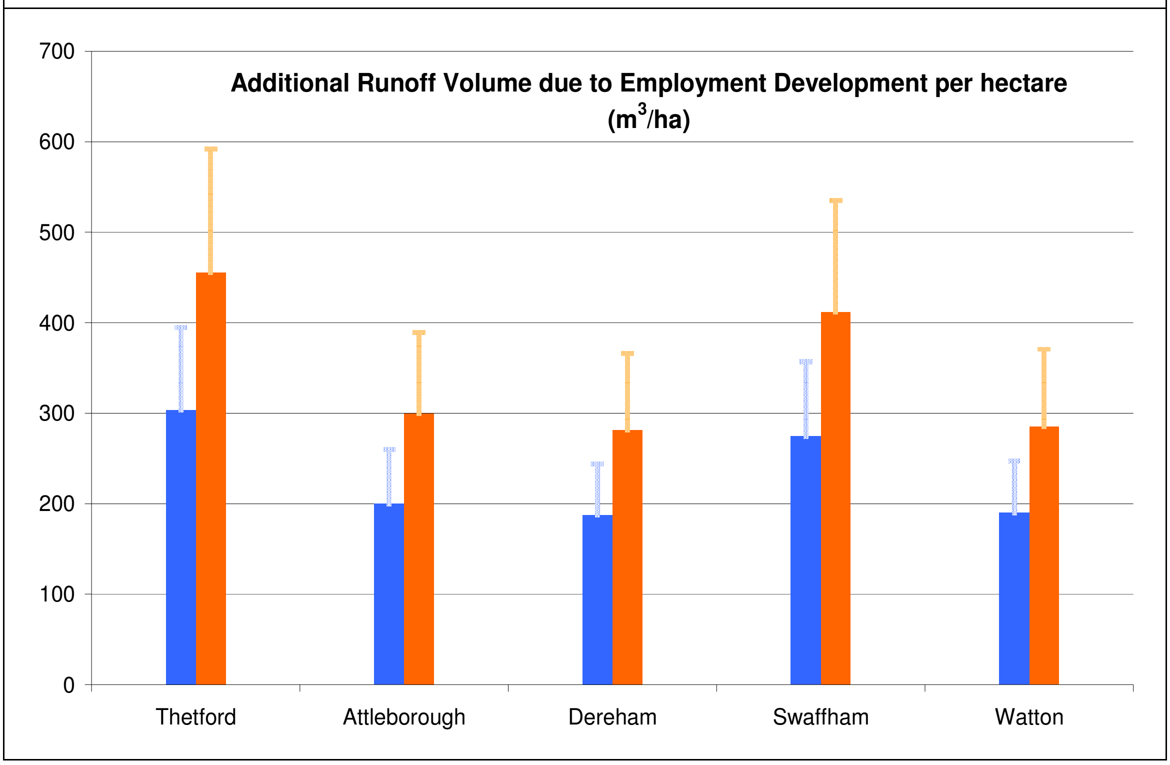
Minimum density, minimum number of houses

Maximum density, maximum number of houses

30% increase due to climate change to 2115

Table 4.2: Additional Runoff Volume due to Employment Development for 1% probability event, 6 hr storm duration





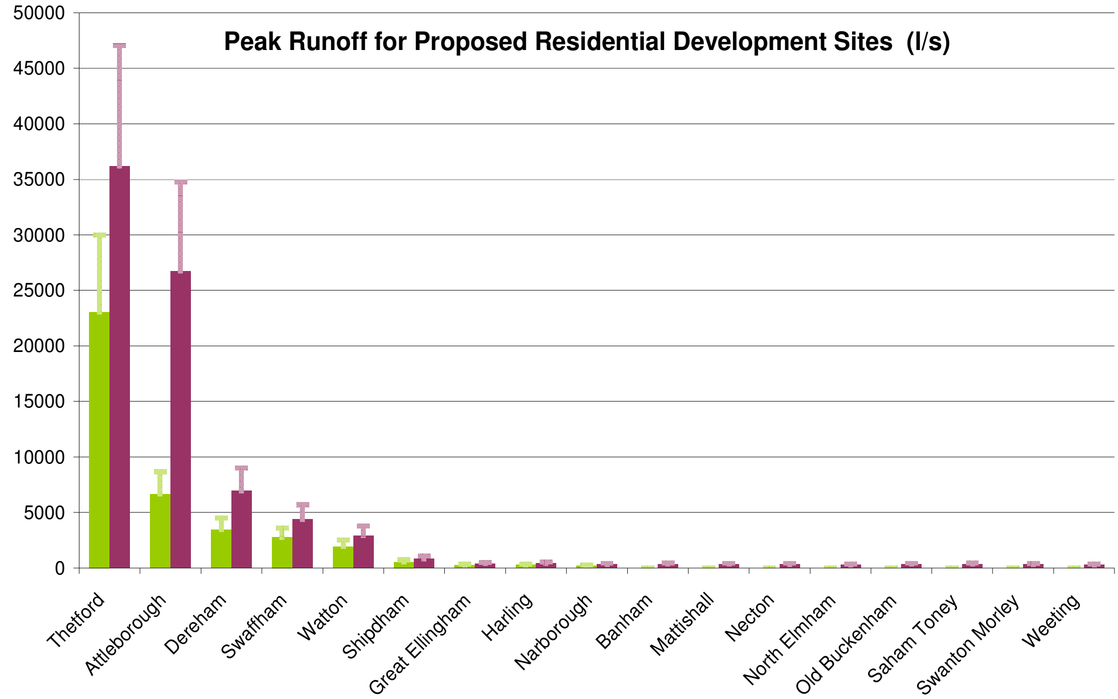
Legend:

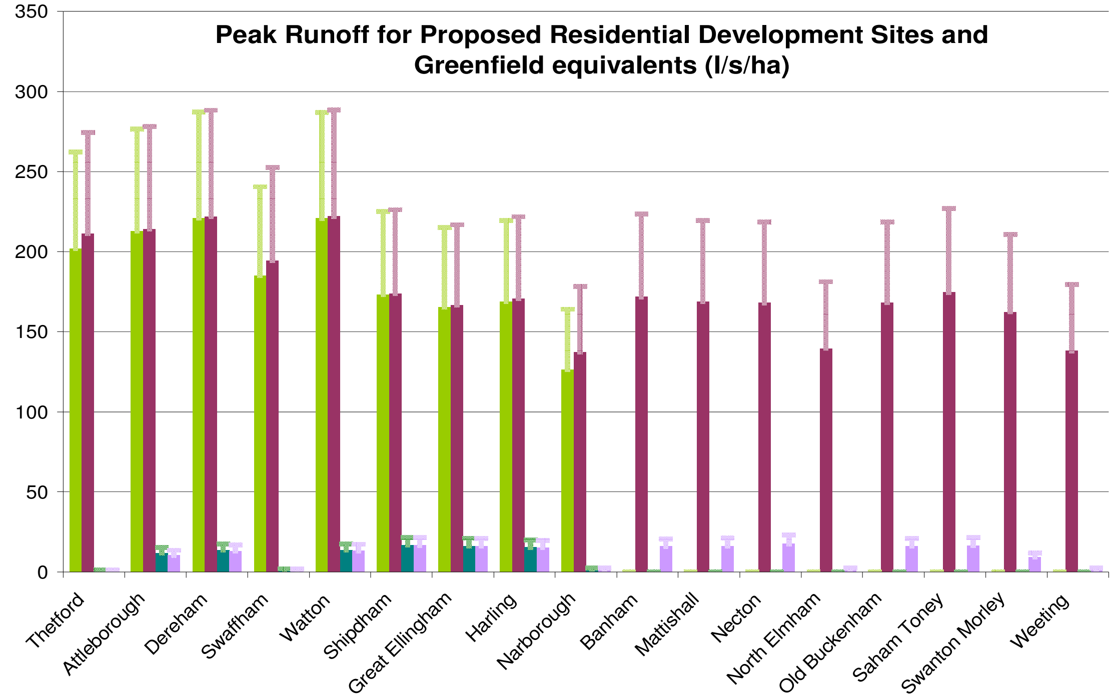
Minimum percentage of impermeable area

Maximum percentage of impermeable area

30% increase due to climate change to 2115

Table 4.3: Peak Runoff for Proposed Residential Development Sites for 1% probability event

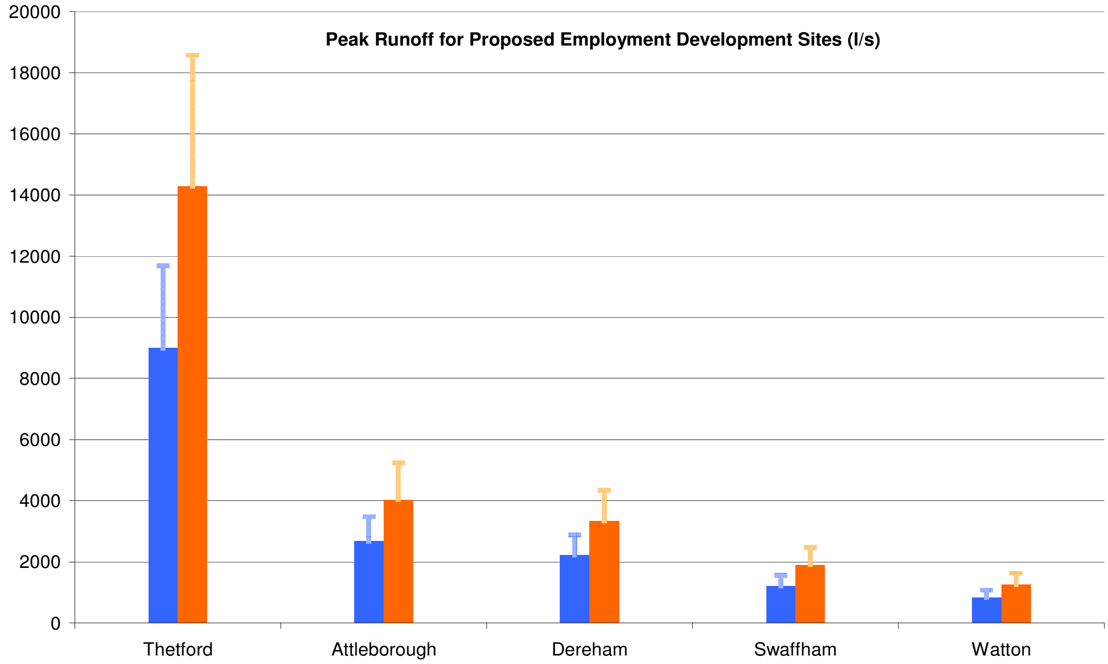


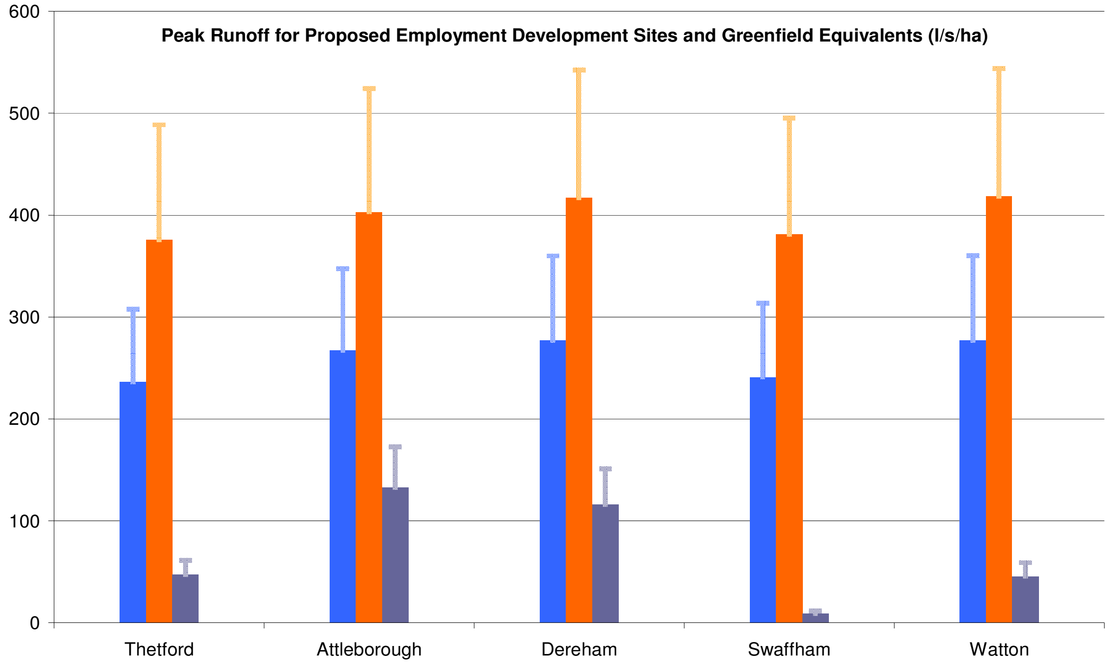


Legend:

- Developed Site - Minimum density, minimum number of houses
- Developed Site - Maximum density, maximum number of houses
- Greenfield Site - Minimum density, minimum number of houses
- Greenfield Site - Minimum density, minimum number of houses
- 30% increase due to climate change to 2115

Table 4.4: Peak Runoff for Proposed Employment Development Sites for 1% probability event





Legend:

- Developed Site - Minimum percentage of impermeable area
- Developed Site - Maximum percentage of impermeable area
- Greenfield Site
- 30% increase due to climate change to 2115

4.2 Assessment of Existing Flood Defences

The EA report that they have no formal flood defences in Breckland District. The Norfolk Rivers IDB and East Harling IDB also report that they maintain no formal defences. These statements are backed up by site visits undertaken during the SFRA study which have not identified any formal flood defence structures.

4.3 Impact of Climate Change on the Flood Risk

Table 4.5 shows the climate change scenarios for peak rainfall intensity and peak river flow which are recommended in PPS25.

Table 4.5: PPS25 Climate change scenarios for peak rainfall intensity and peak river flow

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak Rainfall Intensity	+5%	+10%	+20%	+30%
Peak River Flow	+10%	+20%		

The lifetimes of the developments are likely to be at least 50 years, however there is no precise information available at the moment. By agreement with the Breckland Council the following scenarios have therefore been tested:

- addition of 20% and 30% to the 1% design peak rainfall intensity used for the present day analysis,
- addition of 20% to the 1% design peak river flows used for the present day analysis.

Appendix A: Flood Risk Assessments for Proposed Development Areas

This section details each Proposed Development Area. It documents the available data, describes the methodology specific to each site for delineating the flood zones and observations are made on the level of flood risk to each town.

In several cases watercourses are referred to by more than one name according to the source of information. The names used for the watercourses in this report are those assessed to be in most common use, or based on an adjacent feature.

Where a property is listed as being “at risk” this means that it has been assessed that in a flood event of severity 1% or greater, water would reach a level which was likely to cause flood damage to residential or commercial buildings. Unless otherwise stated, assessments are made with the assumption that all flooding has resulted due to the studied river alone, rather than the flooding being due to overland flow, sewer flooding or any other source.

Unless otherwise stated, inspections have been carried out from the upstream extent to the downstream extent of the channel length being studied.

Maps showing the watercourses studied and the 1% flood extent for each of the Proposed Development Areas can be folded out from Appendix C.

A.1 Attleborough

Development sites proposed for Attleborough include farmland to the south west of the town, north of the town and to the south east of the Norwich – Ely railway line. Figure A.1 shows the location of the development sites.

There are no Main Rivers in Attleborough and the town is located in the headwaters of the River Thet. There are a number of ordinary watercourses shown on Figures C:A1 – C:A3, which have been assessed in terms of flood risk.

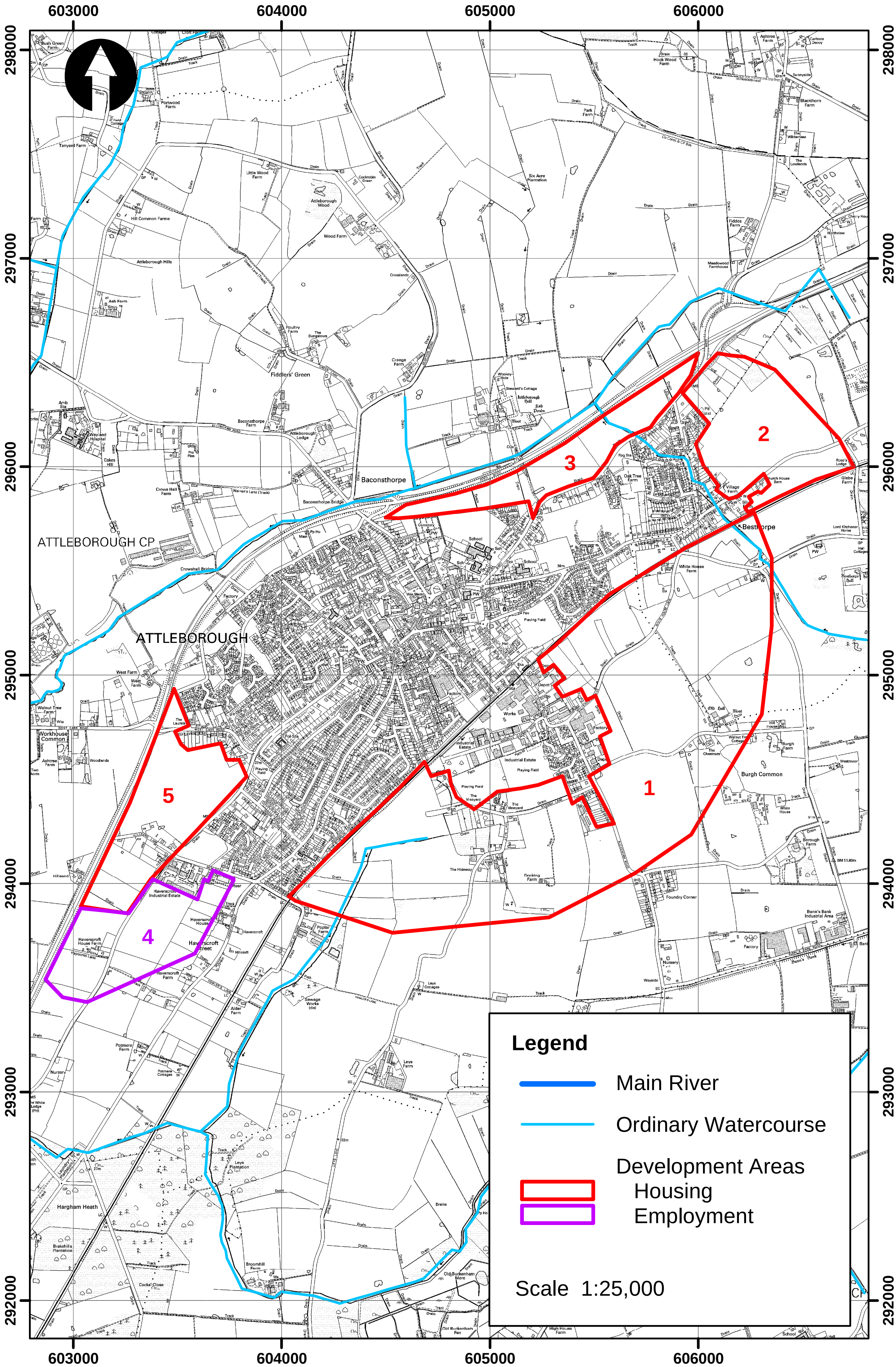
There is some history of flooding from Besthorpe Stream at Mill Lane and from the main Attleborough Stream north of the A11. The main Attleborough Stream does not flow through any of the proposed development sites. There are some ditch capacity issues in the area of Besthorpe, and sandbags have been delivered at several occasions.

The north and north east areas of Attleborough and Besthorpe drain to a tributary of the Thet which flows alongside the northern edge of the A11 bypass road and joins the Thet at Swangey Fen. The southern and western part of Attleborough, including most of the development site to the south and east of the railway, drains to the south, via an East Harling IDB drain which forms the main River Thet at Swangey Fen.

There are no existing studies relevant to the area, and no survey data for any of the ordinary watercourses. The strategic flood risk assessment throughout Attleborough was undertaken by adopting the Level A mapping approach for all the watercourses. A total length of 4.5 kilometres of watercourse was studied in this manner.

Surface water flooding is reported to have occurred on the A11 to the north of Attleborough at several locations.

Attleborough **Figure A.1**



A.1.1 Attleborough Site 1 (South East of Railway)

These watercourses were studied on the 1 and 2 December 2004.

This possible residential development site is agricultural land to the south and east of the railway line in Attleborough. It generally slopes from south-east to north-west. The north eastern part of the site drains into Besthorpe Stream, which flows north-west through Attleborough. The rest of the site drains to the south west, via an East Harling IDB drain to the River Thet. There are numerous drainage ditches in this area.

Besthorpe Stream

Besthorpe Stream drains an area of 2.4 km upstream of the railway line. It flows under Bunwell Road, where it is crossed by an arch bridge with at least a metre clearance. This is unlikely to become blocked. The stream then flows for 250 m in a defined valley until it flows under the railway line. The bridge under the railway has a large capacity and will not restrict flow. About 40 m upstream of the railway the channel is crossed by a farm track bridge. This is unlikely to significantly affect the water levels during flood conditions.

The floodplain of this stream is defined by the valley. On the right bank the 1 % floodplain will be a narrow corridor 10-15 m wide. On the left bank the 1% floodplain will cover the area between the stream and a parallel drainage ditch.

A ditch drains the field on the left of the stream. This will pose no additional flood risk.

Figure A.2: Besthorpe Stream running from right to left along tree line

Downstream of the railway line, and outside of the possible development sites, there are known areas of flood risk where Besthorpe Stream flows through a series of culverts through the Besthorpe area of Attleborough. First the stream passes under Besthorpe Road through an arch bridge which will not significantly affect the flow. The right bank floodplain is lower than the left in this location. Further downstream the stream enters into a culvert which flows under Mill Lane. This culvert is approximately 2 m wide and 1 m high and the entrance is covered by a large trash screen. Flooding of properties has been experienced in this area in the past few years, and was attributed to blockage of the trash screen. During high flows conditions it is expected that water will leave the stream on the right bank upstream of the culvert and spill down Mill Lane along the path of the culvert.

The stream exits the Mill Lane culvert adjacent to Ferguson Way. It flows in a 2 metre deep and well maintained channel between the houses for 150 metres before entering another, similar capacity culvert. This culvert has a high flow trash screen and is probably less susceptible to blockage than the Mill Lane culvert upstream. However, in the 1% flood it is expected that water will spill out-of-bank and flow above ground along the path of the culvert.

The exit of this culvert is on the north side of Norwich Road, at which point Besthorpe Stream enters another possible development site, Attleborough North.

Properties at Risk:

No. 20, 22 and 24 Mill Lane.

Risk to Possible Development:

It is assessed that development should be avoided within a 100 m corridor adjacent to the stream upstream of the railway line. Drainage will require attenuation to ensure that flooding further downstream Besthorpe Stream is not exacerbated.

Other Information:

We had an informal discussion with the owners of No. 20 Mill Lane. Property had been flooded in 1997 and 1998 due to blockages of the trash screen at the upstream end of the culvert under Mill Lane. Since this flooding the screen has been well maintained.

Access for Inspection:

Good access via Bunwell Road, Mill Lane and Ferguson Way.

Whitehouse Lane Drain

This drain is on the north side of Whitehouse Lane and collects several drains which flow into it from the fields on the north and south of the road. The water in the drain flows from east to west alongside the road. The studied reach has a length of 350 metres.

At the upstream, easterly end the drain flows adjacent to a field. There are no structures along this short length. The area at risk of flooding in this area is Whitehouse Lane and a narrow strip of the field on the right bank.

The drain passes adjacent to a property. Drains join the Whitehouse Lane Ditch that flow along either boundary of the property. These are unlikely to pose a significant flood risk. In front of the property the drain has been canalised with a trapezoidal channel constructed from concrete. This has a width of approximately 0.5 metres and a similar depth. Low points in the left bank mean that the road is more susceptible to flooding than the property.

To allow access to the property the drain has been culverted through a small, 0.2 metre diameter pipe. This is likely to block and will cause water to spill onto Whitehouse Lane and run down the road in a westerly direction. The drain outside of the property is shown in Figure A.3.

Figure A.3: Whitehouse Lane Drain looking upstream (east) adjacent to property

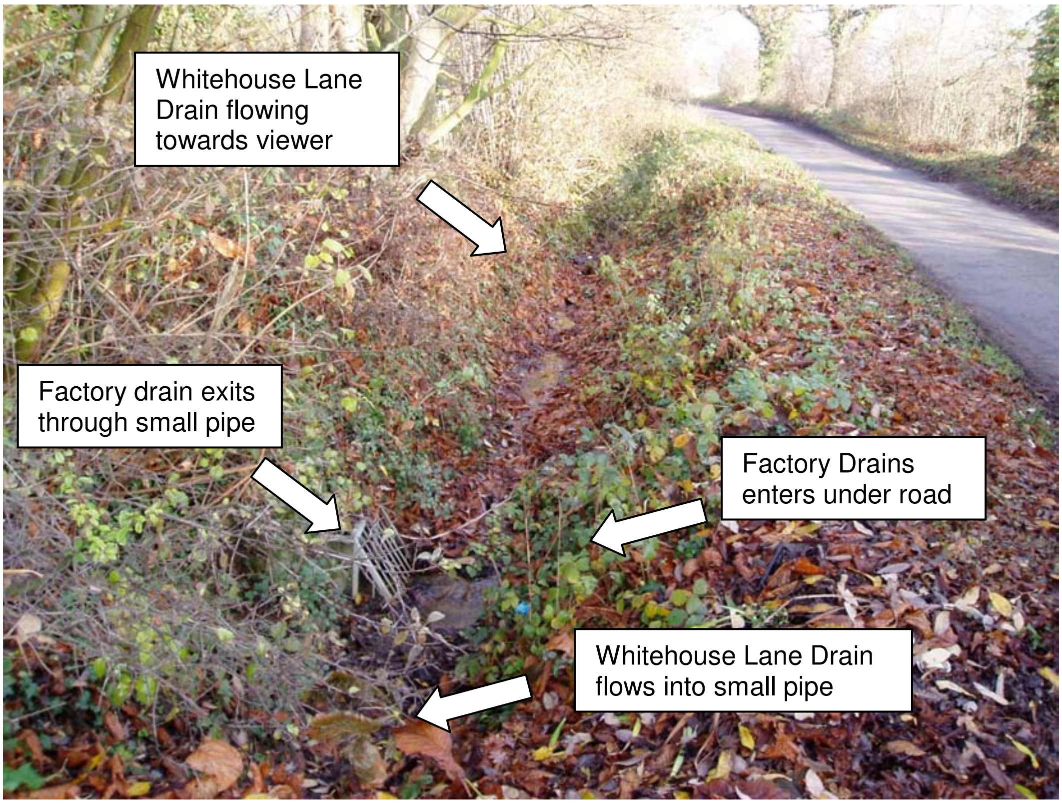
Whitehouse Lane Drain then flows between another field and the road. The drain is overgrown and considerable fly tipping of rubbish bags into the drain has taken place. This has blocked the drain in several locations and during high flow conditions will cause flooding of the road and the field on the north bank.

A drain flows into Whitehouse Lane Drain across the field to the north of the channel. It is overgrown and has no structures along its length. The low area of the field, where it joins Whitehouse Lane Drain is within the floodplain of both ditches.

At the downstream end, closest to the factory at the junction with Station Road, the drain is overgrown. On the left bank the drain is joined by Factory Drain 1 and Factory Drain 2 which flow from south to north. They join and flow in a small piped culvert under Whitehouse Lane to join the Whitehouse Lane Drain. At the point where this culvert enters Whitehouse Lane Drain, there is a cross flow of water. A small piped culvert exits Whitehouse Lane Drain on the right (north bank), shown in Figure A.4. This is covered by a small trash screen, which is likely to be easily blocked by debris during high flow conditions. At the same point Whitehouse Lane Drain enters a small pipe culvert (0.2m diameter).

There is a property on the right bank adjacent to this crossing of the two drains, however, the road is at a lower level and will flood before the property is affected.

Figure A.4: Whitehouse Lane Drain looking upstream



Properties at Risk:

No existing properties are considered to be within the 1% flood envelope.

Risk to Possible Development:

Development should be avoided within 20 metres of the drain.

Access for Inspection:

Good access along Whitehouse Lane

Factory Drain 1

This drains flows across a large field to the south of Whitehouse Lane (Figure A.5), from the Burgh Common Road down the slope to join Whitehouse Lane Drain where the Factory Drains combine and flow through a culvert under Whitehouse Lane (Figure A.4).

There are no structures along this 350 metre drain. It is overgrown. For much of its length the water will remain in bank due to the gradient on the stream. As it reaches Whitehouse Lane, the gradient shallows and in the 1% event, water will spill from the left bank to fill the area between Factory Drain 1 and Factory Drain 2, which runs parallel, approximately 60 metres to the west.

The two Factory Drains join to the south of Whitehouse Lane and pass under the road through a small piped culvert. This is likely to block and will obstruct flow, however, any flooding will be localised as the factory site is protected by an embankment.

Risk to Possible Development:

Development should be avoided adjacent to the 100 m length of the drain closest to Whitehouse Lane (downstream) as this area will be flooded in the 1% event.

Properties at Risk:

No existing properties are within the 1% flood envelope.

Access for Inspection:

Limited access via Whitehouse Lane and the road which runs parallel to it to the south.

Figure A.5: Factory Drain 1 flowing from Left to Right along Hedgerow

Factory Drain 2

There was limited access to this stream. It could only be viewed from Whitehouse Lane where it combined with Factory Drain 1 and flowed through a small culvert under Whitehouse Lane. This ditch is smaller than Factory Drain 2 and is unlikely to be a significant cause of flooding.

Properties at Risk:

None

Risk to Possible Development:

None

Access for Inspection:

Limited access via Whitehouse Lane

Industrial Estate IDB Drain

This is an East Harling IDB drain which flows from the Industrial Estate on Station Road in a south westerly direction and leaves the possible development site at Poplar Farm, to the south of Attleborough. The drain was studied for 1400 metres, from where it exits from a culvert under industrial units on the north side of Maurice Gaymer Road down to Poplar Farm.

At the top of the studied reach the drain exits a culvert under industrial units and flows between an industrial yard and the railway line. The railway line is on a small embankment in this area and the yard is also slightly higher. The channel is around 3 metres wide and about a metre deep. It is well maintained. Flooding will be limited to the narrow corridor of land between the railway and the industrial yard that the channel flows through. This section is shown in Figure A.6.

At the downstream end of this reach the drain enters a box culvert approximately 2 metres wide and 1 metre high. This has a trash screen which has recently been cleared and the debris deposited on the right bank (Figure A.7). If this trash screen is kept clear then the 1% flood event will probably reach bankfull, but water will probably not spill significantly out-of-bank. However, Breckland District Council state that this culvert is poorly maintained, and as such it is likely that water will spill around the headwall of the culvert and to the left across Maurice Gaymer Road, following the path of the culvert. No existing properties are at flood risk in this area.

Figure A.6: Industrial Estate IDB Drain looking upstream

Figure A.7: Entrance to Maurice Gaymer Rd Culvert

The culvert has a length of 60 metres and turns through a ninety degree bend before the drain leaves the culvert in an area of scrubland. The culvert exit is shown in Figure A.8. Water will flow overland above the route of the culvert in the 1% flood event.

Figure A.8: Exit from Maurice Gaymer Road Culvert

Figure A.9: Looking downstream from Maurice Gaymer Rd Culvert

Immediately downstream of the culvert the ditch flows through some disused land. A pipe crosses the stream just above the normal water level and this will significantly obstruct flow, especially if some of the debris in the channel at this point becomes lodged behind it. This obstruction is shown in Figure A.9. The 1% flood flow will cause water to leave the channel in this area and inundate some of the scrubland. No existing properties are considered to be at risk.

The ditch then flows under Slough Lane and through the gardens of several existing properties. The culvert under Slough Lane will cause water to back up behind it and in the 1% flood water will spill across the road. Downstream of Slough Lane the ditch is well maintained and there are several structures, including a farm track bridge. These are unlikely to significantly impede flow in flood conditions as it is considered that the 1% event will flood a width of approximately ten metres on either bank.

The IDB drain then turns through ninety degrees and flows in a well defined valley in a south easterly direction, shown in Figure A.10. Several drains enter the drain on the right bank. These have no structures along them and will not flow out-of-bank as they have sufficient gradient to quickly transfer the water into the main IDB drain.

Figure A.10: Attleborough South East of Railway Possible Development Site – Industrial Estate IDB Drain flowing from right to left in valley

The IDB drain exits the possible development site just upstream of Poplar Farm. In this area the ditch is 1.5 to 2 metres deep and about 5 metres wide at bankfull. There are no structures along this length and flooding will be restricted to a narrow strip of land adjacent to the ditch.

Risk to Possible Development:

It is assessed that development should not take place along a corridor of 30 metres either side of the channel.

Properties at Risk:

There are no existing properties considered to be at flood risk in this area.

Access for Inspection:

Via Maurice Gaymer Road and cycle path linking it to Slough Lane. Also via Poplar Farm.

A.1.2 Attleborough Site 2 (Besthorpe)

This area was studied on the 2 December 2004.

This possible residential development site comprises land to the north east of Attleborough. It is presently arable land. It is bounded by Bunwell Road to the south, existing development along Mill Lane to the west and Norwich Road to the north.

There is just one drainage ditch in this site.

Stubley Farm Drain

This ditch flows from north to south along the eastern boundary of the development site. It is a small ditch and although it contained water, it was not noticeably flowing on 2 December 2004. It flows adjacent to a hedgerow for 400 metres and is overgrown.

Channel and Floodplain:

There is no significant flood risk associated with this ditch as the 1% event is unlikely to exceed bankfull levels.

Properties at Risk:

No existing properties are at risk of flooding.

Risk to Possible Development:

None

Access for Inspection:

Via Besthorpe Road.

A.1.3 Attleborough Site 3 (North)

This area was studied on the 2 December 2004.

This possible residential development site is bordered by the B1077 Norwich Road to the south and the A11 Attleborough bypass to the north. The A11 is built on a raised embankment as it passes the possible development site. The site is presently grassland and slopes from north to south, towards the A11 road. The site has a number of drainage ditches and is also crossed by Besthorpe Stream.

Besthorpe Stream

This stream has a catchment area of 3.3 km^2 and has a bankfull width of approximately 4.5 m and a bank height of 2 m on both banks.

Upstream of the site the stream flows through the Besthorpe area of Attleborough in a series of culverts under Mill Lane and Norwich Road. This section of the stream is described in Section A.1.1.

Immediately upstream of the possible development site the stream flows through a 130 metre long culvert. It then flows across grassland for 175 metres and passes under the A11 embankment in a culvert. No access was obtained to this culvert, however it is presumed that the culvert has sufficient capacity to transmit the 1% flow without significant backwater effects.

Floodplain:

The land on the left bank of the stream is at a lower elevation to that on the right bank. Therefore, flooding in the 1% event is limited to the left bank, extending 10 to 15 metres away from the channel.

Properties at Risk:

There are no existing properties at flood risk.

Risk to Possible Development:

It is assessed that development should not occur within 20 metres of the left bank of the channel.

Access for Inspection:

Limited access via Norwich Road

Mill Lane Drain

This drain flows from south to north from the junction of Mill Lane and Norwich Road to the A11, a length of 100 metres. There is a garage on the left bank next to Norwich Road, otherwise the ditch is bordered by fields and flows along a hedgerow.

Channel:

The ditch was overgrown. It was about three metres wide at bankfull and about 1.5 metres deep, with the land on the right bank being slightly lower.

Floodplain:

The ditch will not pose a significant flood risk.

Properties at Risk:

No exiting properties are at risk.

Access for Inspection:

Limited access via Norwich Road

Plumstead Drive Drains

These two drains cross the fields behind Plumstead Drive. No access was obtained to these drains, but given there small catchment areas they are unlikely to pose a significant flood risk.

A.1.4 Attleborough Site 4 (Haverscroft Street)

This area was studied on the 1 December 2004.

This possible employment development site is located to the south of Attleborough around the hamlet of Haverscroft Street. It is bounded by the Havercroft Street in the east, the A11 road in the west and the exiting boundary of Attleborough in the north. To the south the site extends as far as Haverscroft Farm and Haverscroft House Farm.

Flowers Lane Drain

This 300 metre long drain flows from south to north along the eastern edge of Hargham Road, before turning through ninety degrees and flowing along the southern edge of Flowers Lane until it flows under the railway at the edge of the possible development site.

At the upstream end, where the drain flows alongside Hargham Road the ditch is small with little flow and has limited flood extents. It then flows in a 0.3 metre diameter culvert under the entrances to several properties. This will cause water to back up. However, in the 1% flood event flooding will be limited to a narrow strip of land 5-10 metres wide between the ditch and the road.

On the corner of Hargham Road and Flowers Lane the drain is open for a length of around ten metres before flowing through another 0.3 metre diameter culvert for around 30 metres. At this point the ditch was visibly flowing and well maintained. The left bank is lower and in an event smaller than the 1% event the combination of the restricted capacity of the downstream culvert and the low left bank will cause water to spill out of the left bank onto the junction of Flowers Lane and Hargham Road.

Alongside Flowers Lane the drain flows in a well maintained channel with cut grass banks. This is shown in Figure A.11. It is about 1.5 metres deep and 4 metres wide at bankfull. Water was observed to be flowing quickly down towards the railway. A 0.5 metre diameter pipe transfers the water under the railway. This has a restricted capacity which will lead to water backing up and spilling onto the lane. Water will not spill over the railway line as this is at a slightly higher elevation. Flowers Lane on the left bank is considerably lower than the field on the right bank and this area will flood in the 1% event.

Properties at Risk:

No existing properties are considered to be within the 1% flood envelope.

Risk to Possible Development:

Development should be avoided within 10 metres of the drain.

Other Information:

The Level Crossing Guard has been working at this site for nine years and has no recollection of any flooding at the site or any problems with the culvert in this time.

Access for Inspection:

Good access via Flowers Lane

Figure A.11: Flowers Lane Drain Looking Downstream Towards the Railway

Fowler's Lane Drain

This 300 metre drain flows from north to south along the eastern edge of Hargham Road before turning through ninety degrees and flowing along the edge of a field adjacent to Fowler's Lane. It then passes under the railway line in a 0.2 metre diameter pipe.

Adjacent to Hargham Road the ditch is approximately 0.3 metres wide at normal flow and about 2 metres wide at the bank top. Water was not flowing on 2 December 2004 and it is assessed that it is unlikely to spill out of its banks even in the 1% flood event.

Alongside Fowler's Lane the ditch was observed to be flowing. The ditch is 0.4 metres wide during normal flow conditions and about 4 metres wide at the bank top. The channel is 1 – 1.5 metres deep, getting deeper closer to the railway line.

Fowler's Lane Ditch flows through a small, 0.2 metre diameter pipe culvert under the railway line and out of the possible development site. This culvert will be prone to blockage and backing-up during high flow conditions. This will cause the lowest corner of the field on the left bank of the drain to flood. Flood water will not spill over the railway line.

Properties at Risk:

No existing properties are at risk from flooding.

Risk to Possible Development:

Development should be avoided within 10 metres of the drain.

Access for Inspection:

Good access via Hargham Road and Fowler's Lane.

London Road Drains

These drains are located between Haverscroft House farm and Haverscroft Industrial Estate. They consist of a main drain which flows from south to north alongside London Road and a number of field ditches which outfall into this drain. They have a combined length of 800 metres.

To the south these drains are on the west side of London Road. They are 0.4 metres wide at the base and 3-4 metres wide at field level. The channels are approximately 1.5 metres deep.

The ditches are reasonably well maintained with cut banks, as shown in Figure A12. There are several structures where gateways enter the fields which may cause localised flooding problems if the culverts under them are blocked.

Given the depth and hence large capacity of these drains, and their small catchment contributing areas, the 1% flood event is assessed to remain within the channel.

Figure A.12: London Road Drain (draining land to west of London Road)

Further downstream, to the north, adjacent to Haverscroft Industrial Estate, the drain is located on the opposite, east side of London Road. We have been unable to locate the exact point where the drain crosses the road, but it seems reasonable to presume that this is the case.

At this location the channel is 2-3 metres wide and 1.5 metres deep. It is well maintained, but a 0.2 metre pipe culvert at the downstream end will greatly restrict flow in high flow conditions. This is shown in Figure A.13. This restriction will cause a narrow corridor between the road and the industrial estate to flood. There is an embankment on the edge of the industrial estate that will prevent flood water inundating this area.

Properties at Risk:

No existing properties are considered to be at flood risk.

Risk to Possible Development:

Development should be avoided within 10 metres of the drain.

Access for Inspection:

Via London Road.

Figure A.13: London Road Ditch adjacent to Haverscroft Industrial Estate

A.1.5 Attleborough Site 5 (London Road)

This area was studied on 2 December 2004.

This possible development site is to the south west of Attleborough. It is bounded by the A11 Attleborough bypass to the west, London Road to the east, properties on West Carr Road to the north and properties adjacent to Hillsend Lane to the south. It is presently agricultural land.

Site visits have revealed that there are no open watercourses within this potential development site.

A.2 Dereham

The possible development sites surrounding Dereham are all currently farmland. They are shown on Figure A.14.

Dereham is in close proximity to three watercourses, the River Tud, Dereham Stream and Wendling Beck. The possible development site to the south of Dereham is bordered by the River Tud. There is a limited floodplain in this area as the land rises steeply away from the river. The development site to the west of the town is bordered to the north by Wendling Beck and Dereham Stream. Wendling Beck has a limited floodplain as the land rises quickly away from the river and an embankment borders the possible development site. Dereham Stream is susceptible to blockages due to the numerous structures along its length, as it passes through Dereham. There is also an unnamed drain which borders the development site to the north of Dereham, near Galleymoor Farm.

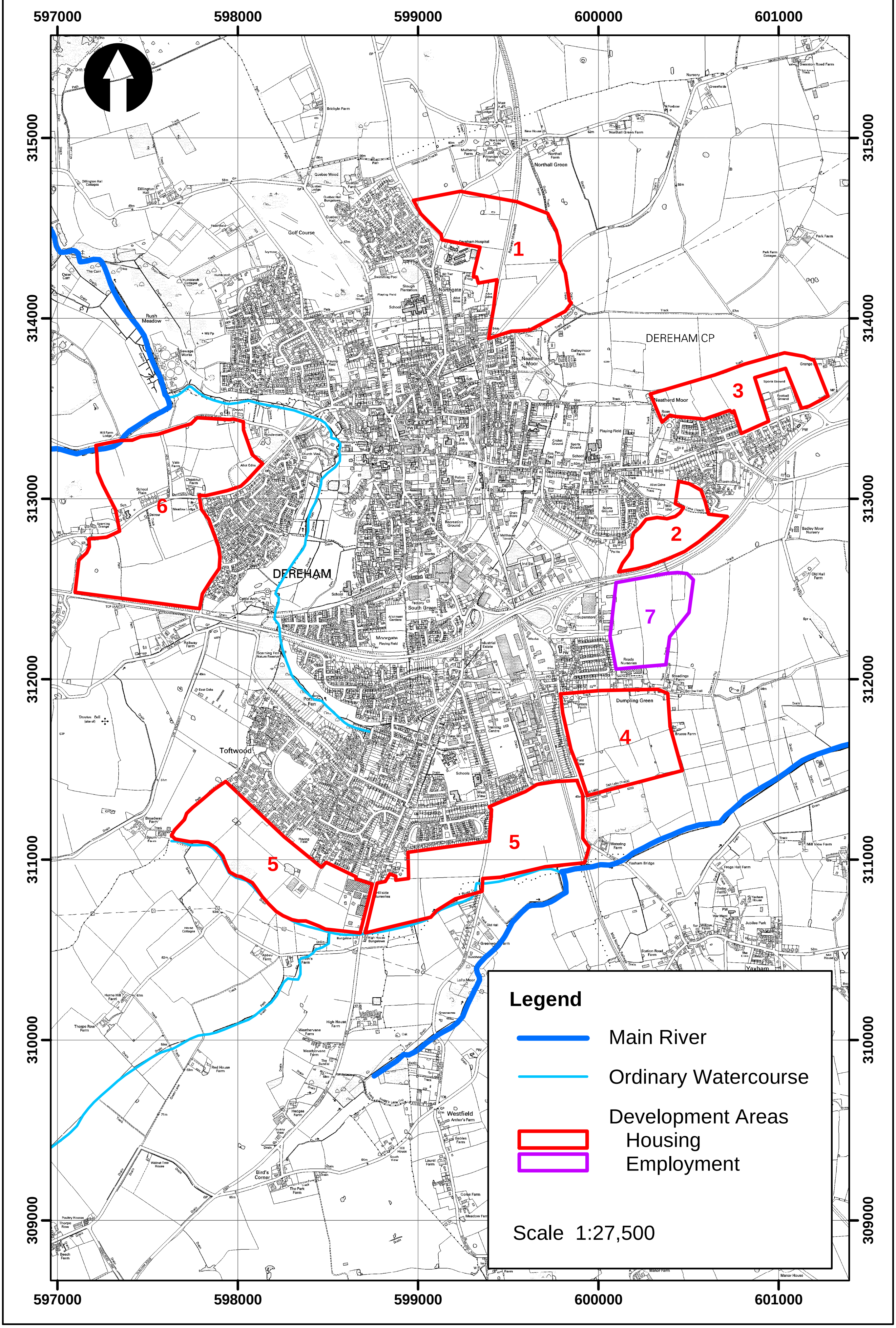
Dereham Stream experiences numerous localised flooding problems, largely due to constraints of the channel capacity at structures. Properties at Toftwood and Swanton Road are reported by BDC to have been affected recently.

Wendling Beck flood outlines have been produced as part of the Upper River Wensum Strategy Study (BBR, 2004). The River Tud model has been modelled as part of the River Yare Flood Risk Study (BBR, 2005). Dereham Stream has also been modelled. The use of these models is documented in Appendix D. The remainder of the ordinary watercourses in Dereham were studied using the Level A mapping technique. The development sites showing the 1% fluvial flood outline are given in Figures C:B1 to C:B3.

In addition to the fluvial flooding from Dereham Stream, Dereham also has some history of surface water flooding, sewer flooding and infrastructure failure. The EA has reported that Dereham has been flooded by surface water in June 2007. Surface water flooding occurred on A47 at several locations through the town. As highlighted in the Broadlands River CFMP, East Dereham is heavily reliant on maintenance and pumping. Records from Breckland Council show that it has been flooded in St George Drive due to a blocked pipe and in a garden in Larner’s Drift, Toftwood, due to undersized pipes under the garage. Sewer flooding occurred throughout the town, with a critical point in the North-East of Dereham at Swanton Road. According to the Environment Agency, sewer flooding in Larner’s Drift and Lavender Grove occurred in a number of recent years due the unauthorised connection of surface water drainage facilities into the foul sewer.

Dereham

Figure A.14



A.2.1 Dereham Site 1 (Swanton Road)

These watercourses were studied on the 2 December 2004

The entire site slopes gradually toward Galleymoor Farm in the south-east. The site is artificially divided into three catchments by the B1147 and a disused railway. The site is in the headwaters of the Dereham Stream catchment and all ordinary watercourses eventually flow into Dereham Stream. Three watercourses in the possible development site have been studied. The source of each of these ditches, and the areas they drain should be identified as part of a site specific FRA.

It should also be noted that sewers just downstream of the site on Swanton Road are prone to flooding. This should be taken into account when designing the new storm and foul water sewage drainage networks, to ensure that the development does not exacerbate the problem. Similarly, the development should ensure that the discharge to the Dereham Stream is not increased, especially as there is some history of flooding of the stream just downstream of the site in Swanton Road.

As discussed in Section 4.1 of the report, it is not be sufficient to cap the peak discharge from new development sites to the greenfield rate. It is also necessary to provide long term storage solutions, which enable a volume equal to the greenfield runoff to discharge at greenfield rate, while retaining the rest of the runoff to discharge as infiltration or at very low rates. It is particularly important for the Dereham Stream, which already experiences regular flooding incidents, that the channel capacity is not reduced over a long period of time following a significant rainfall event.

Dereham Hospital OW 1

This drain is an ordinary watercourse on the border of the possible development site. It is a small ditch which flows adjacent to a farm track. At the time of study the drain had been recently cleared.

The length of the studied section is approximately 180m from Swanton Road to the confluence with OW3

Channel:

The watercourse is a shallow drainage ditch which is initially 1.1m deep, but the depth quickly increases to 1.6m. The banks are slightly higher on the right bank, next to the track.

There is one structure in the studied section, a 200mm diameter pipe culvert under a farm access road. The culvert invert is slightly raised from the channel bed so water backs up at the culvert.

Floodplain:

It is assessed that due to the limited capacity of the culvert there is the potential for flooding from this watercourse. Any flooding however would be localised due to the small catchment.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that the risk of flooding to possible development is limited due to the size of the catchment.

Access for Inspection:

Access via Galleymoor Farm access track.

Dereham Hospital OW2

This drain is an ordinary watercourse on the border of the possible development site. It is a small ditch which flows from north to south across the B1147.

The length of the studied section is approximately 500m from upstream of the B1147 to a forested area just outside of the possible development site.

Channel:

The watercourse is a shallow drainage ditch which is initially 1.1m deep. The conditions of the channel Upstream of the B1147 remain constant. There is one structure in the studied section; a 300mm diameter pipe culvert under the B1174 which is partially silted. Downstream of the culvert the channel is slightly smaller and overgrown.

The channel continues for approximately 30m, but then seems to disappear. No culvert could be found in the area. The surface flow would continue down the footpath, which initially is next to the channel. The footpath has banks over 1.7m high on either side and would initially be very effective as a channel; however further downstream the banks on the footpath disappear and the path starts to go uphill. The surface water flowing down the footpath would flow into the forested area, which has two ponds.

Floodplain:

It is assessed that there is the potential for flooding from this watercourse. This flooding would occur on the border of the possible development site and especially in the forested area. This flooding could be easily alleviated by cutting new drains and improving the maintenance of the drains.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that the risk of flooding to possible development site is limited. The drains would need to be improved to reduce the risk of flooding from surface run-off further downstream.

Access for Inspection:

Access via Galleymoor Farm access track.

East of Neatherd Moor OW3

OW3 is an ordinary watercourse on the border of the possible development site. It is a small ditch which flows from the footpath near a forested area to Neatherd Moor. OW1 is a tributary of this drain.

The length of the studied section is approximately 385m.

Channel:

The watercourse is a shallow drainage ditch which is initially 1m deep. The channel conditions remain constant, until the confluence with OW1. Downstream of this point there is a small length of channel, upstream of a culvert under the farm access road which is overgrown. The culvert has been crushed by the farm traffic and the water now flows over the track.

Downstream of the culvert the channel is just over 1m deep with vegetation on both banks, but is largely clear.

Floodplain:

It is assessed that at present this watercourse is at risk of flooding in the 1% flood event. This is due to the channel blockage at the farm track. Water backing up at the farm access would cause flooding to the neighbouring fields and the farm track. The flood water would be outside of the possible development site but must be considered.

This flooding could be easily alleviated by improving the maintenance of the drains.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that the risk of flooding to possible development site is limited. However as this drain network is the main link between the site and Dereham stream it is important that it is properly maintained.

The drains would need to be improved to reduce the risk of flooding from surface run-off further downstream.

Access for Inspection:

Access via Galleymoor Farm access track.

A.2.2 Dereham Site 2 (Mill Site)

The site was studied on 2 December 2004

The site slopes gradually away from the centre in all directions.

There is already development taking place on the eastern and western edges of the possible development site.

There are no watercourses in the possible development site. Storm and foul water sewage drainage networks have already been put in at the site.

There is some history of surface water on the A47 to the south of the site. However it is assessed that there is no risk to the development.

A.2.3 Dereham Site 3 (Norwich Road)

These watercourses were studied on 2 December 2004

The whole site slopes gradually from west to east. The site is in the headwaters of the Dereham Stream catchment and all ordinary watercourses eventually flow into Dereham Stream. Four watercourses in the possible development site have been studied.

Neatherd Moor Drains

These drains are ordinary watercourses which flow in the north of the possible development site. There are four drains in this system the first flows along the border of the possible development, while the other three flow into this drain from the possible development site. The total length of the studied drains is approximately 750m.

Channel & Flooplain:

The larger watercourse is a shallow drainage ditch which flows along a track on the border of the possible development site. In the upstream section of this drain there are a few blockages. The upstream section is up to 1m deep but the depth of the channel does fluctuate. On the right bank of the watercourse there is an un-surfaced track with a small embankment after that. Flooding of the right bank would be restricted to the track.

The three drains which flow into the first drain all have similar characteristics. They are all approximately 40cm deep. The banks of these watercourses become shallower close to the confluence, with a small area at risk of flooding in these locations. The size of these drains and the catchment means that any flooding from these small drains would be limited in extent.

Downstream of the drain flowing from Rose Farm the channel becomes wider and occasionally deeper. In this area there is little gradient in the land, as a consequence flooding in this area would of a greater extent. At the time of study a blocked culvert in this area had caused a small amount of flooding due upstream (Figure A15)

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that the risk of flooding to possible development is limited.

Access for Inspection:

Access via Rose Farm track.

Figure A.15: Flooding at Neatherd Moor

A.2.4 Dereham Site 4 (Dumpling Green)

These watercourses were studied on 2 December 2004

The whole site slopes toward the south east, the height difference between the top and bottom of the site is approximately 10m.

The site is in the upstream catchment of the River Tud and all ordinary watercourses eventually flow into the Main River. There are a number of connected drainage ditches in the possible development site; which are all part of the same system.

Dumpling Green OW 1

This watercourse runs as an open channel from a track at the northern border to two-thirds of the way down the possible development site. The watercourse has been split into three reaches to aid reporting. The upstream reach flows north to south, the middle reach flows from east to west, while the downstream reach flows from north to south. The length of the studied section is approximately 480m to the confluence.

While the whole site slopes toward the south east, ridges in the fields in the north of the possible development site slope gradually towards these three watercourses.

Channel: Reach 1

The watercourse is a drainage ditch which is initially 1.5m deep, and remains constant throughout. The banks are roughly the same height, however there is a small (15cm) earth embankment on the right bank, 1m away from the channel. Three quarters of the way down the watercourse there is some erosion on the left bank.

There are two other drainage ditches, which flow parallel to the studied watercourse, these watercourses have similar characteristics.

Immediately upstream of the confluence with Reach 2 the channel becomes 50 cm wider.

Channel: Reach 2

Upstream of the confluence with Reach 1 the drainage ditch is small. At the confluence with Reach 1 the watercourse becomes 1.7m deep and approximately 2.4m wide. This drainage channel flows from west to east. The banks of the channel are approximately the same height, with dense vegetation on the right.

The main channel veers off to the right (Reach 3) 10m after the confluence with Reach 1. A secondary channel continues along the same path, for another 10m but is blocked after this point.

Channel: Reach 3

This channel leads off from Reach 2; it has similar dimensions to this channel (2.5m wide, 1.75m deep) except that the left bank is slightly higher, at 1.9m.

At the end of the channel there is a 100 mm diameter culvert which cuts across the field and discharges into Dumpling Green OW 2. The culverted section is approximately 100m long.

Floodplain:

The gradient of the land and the size of the catchment mean that the flood risk from this watercourse system is limited. The areas at risk of flooding are at the sharp bend between Reach 1 and Reach 2 and at the culvert at the downstream end.

The limited size of the culvert would restrict flow and cause water to back up and overtop the banks. This situation would be made worse by the steep gradient in this area. The gradient would limit the volume of water that could back up at the culvert before flooding will occur and cause water to flow down towards Salt Lake track.

Existing Properties at Risk:

Very few properties immediately downstream.

Risk to Possible Development:

It is assessed that there is a risk of localised flooding in the upstream section of this watercourse and the potential for flooding in the south, with water collecting at Salt Lake track

Access for Inspection:

Access via track.

Dumpling Green OW 2

This watercourse runs as an open channel from the centre of the possible development to Salt Lake track and then along Salt Lake track before flowing into another drain which flows into the River Tud.

The length of the studied section is approximately 380m.

Channel:

The watercourse is a drainage ditch which begins 2m deep, and 2.5m wide. The characteristics of the channel change significantly over the studied area. The banks are approximately the same height, however there is a small (15cm) earth embankment on the right bank, 1m away from the channel.

There are two small ponds connected to the channel, the first is ten metres from the start of the studied section while the second in two thirds of the way down the field, both are shown on the OS maps. The channel becomes shallower in this location. The outflow from Dumpling Green OW1 discharges into the downstream pond.

When the watercourse reaches Salt Lake track it veers off to the left, in this area the banks are roughly 0.75m high. At the time of the study water was flowing along the track and into the watercourse at this point.

The channel dimensions quickly return to 2m deep and 2.5m wide as the watercourse follows the track for 100m. In the corner of the possible development is the confluence between this drain and another field drain. Immediately downstream of the confluence there is a 200mm diameter culvert under the Salt Lake track. Downstream of the culvert the channel becomes 3.5m wide and 1.75m deep.

Floodplain:

The gradient of the land and the size of the catchment mean that land at risk of flooding is in the south of the possible development site.

One area which is assessed to be at flood risk is Salt Lake track; the water would come from the watercourse and directly from the land. Another area assessed to be at risk of flooding is close to the culvert which would restrict flows.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is a risk of localised in the south, collecting in Salt Lake track

Access for Inspection:

Access via track.

A.2.5 Dereham Site 5 (Toftwood)

These watercourses were studied on 2 December 2004

The whole site slopes toward the River Tud which borders the south of the possible development site. The height difference between the top and bottom of the site is approximately 6m.

The site is at the upstream catchment of the River Tud and all ordinary watercourses in the site flow into the Main River. The site is currently agricultural land; no details are currently available about potential development.

There is some history of sewer flooding and flooding due to infrastructure failure in the Toftwood area to the north of the site. It is recommended to ensure that this will not affect the new development.

Toftwood Drain

This watercourse flows along the western border of the potential development site. The studied reach runs from Strasbourg Way to Spurn Farm, where it flows into the River Tud, which becomes Main River.

The total length of the studied section is 490m.

Channel & Floodplain:

The watercourse is a drainage ditch which starts around 1.5m deep, and gradually increases in depth downstream. The banks on the right bank are slightly lower in the upstream region, but then remain roughly the same height.

Close to the upstream limit of the studied area there is a pond near the drain with an outfall pipe coming from the possible development three quarters of the way down the watercourse.
There are no other structures in the studied area.

The watercourse flows into the River Tud where a lake has formed at the upstream limit due to a blockage in the channel; this area has a 2m embankment on the right bank.

The gradient of the land and the size of the catchment mean that the flood risk from this watercourse would be localised.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is a risk of localised flooding in the upstream section of this watercourse and the potential for flooding in the south, with water collecting near Spurn Farm

Access for Inspection:

Access via path.

A.2.6 Dereham Site 6 (Rushmeadow)

This possible development site is located to the west of the town. The A47 is at the southern boundary of the site with Rush Meadow Road to the north. It is presently arable farmland with some development, including a school. There is a good fall across the site towards Wendling Beck in the north, although southern parts of the site drain towards a tributary of the Dereham Stream.

Wendling Brook is the only identified open watercourse in the area, this was modelled by Babtie, Brown and Root in 2003, details are given in Appendix D9. The development site and fluvial flood risk areas are identified in Figure C:B4.

Sandbags were requested in June 2007 at the School Plain. However there is no certainty that the site did actually flood, or from which source this might have been.

A.2.7 Dereham Site 7 (Walpole Loke)

This possible employment development is located to the east of the town. The A47 is at the northern boundary of the site with the Dumpling Green proposed development site to the south. It is presently arable farmland. The land generally slopes to the south-east, towards the site 4 and the River Tud.

A.3 Swaffham

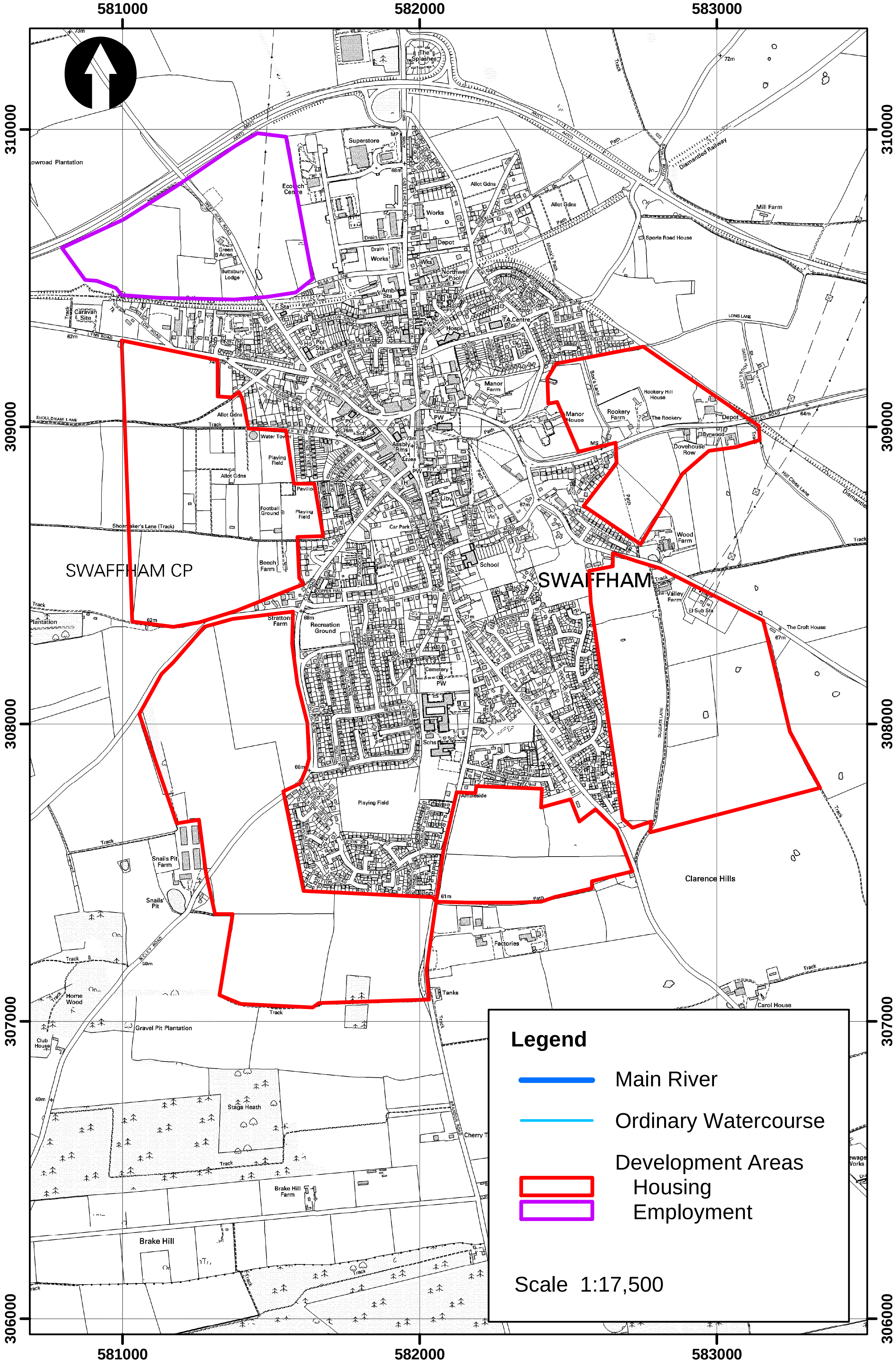
The town of Swaffham is at least 4 km from any Main River, and well outside the Extreme Flood Outline. It is therefore considered not to be at flood risk from this source. In addition, there are no watercourses marked on the Ordnance Survey maps in the Swaffham area, see Figure A.16. A site visit has shown that Swaffham is generally higher than the area surrounding it and there are no watercourses in the valleys surrounding the town, or surface water collecting in low areas.

The town lies on a chalk basin, covered with poorly draining clay soils. This means that flooding may occur due to the collection of surface water from precipitation. At present there is no positive drainage system for the town, with surface water either draining to deep drainage boreholes direct to the chalk aquifer or pumped to the River Wissey at North Pickenham.

The Breckland District Council has reported surface water flooding incidents in Northwell Road. The Lynn News has reported regular sewer flooding in Sporle Road, New Sporle Road and West Acre Road. The Highways Agency reported a surface water incident on the A47 sliproad to the west of the town.

The six possible development sites around Swaffham are currently farmland, with some playing fields to the west of the town. It is proposed to develop them into residential areas, apart from the site to the north-west of the town which would be released for employment development.

Swaffham **Figure A.16**



A.4 Thetford

Thetford was studied on 1 December 2004.

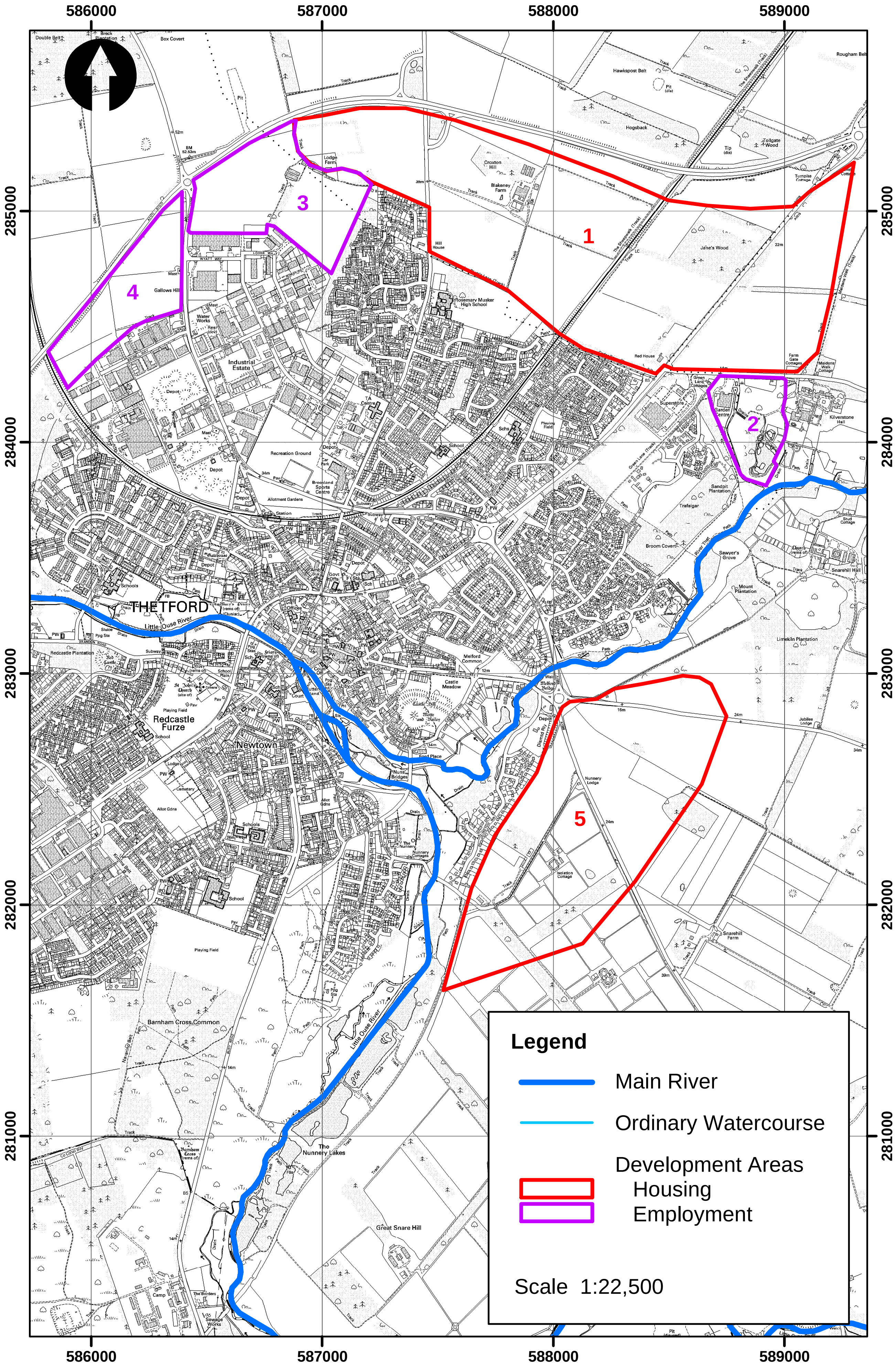
Thetford is located in the south west of Breckland, at the confluence of the River Thet and Little Ouse River. The two rivers join in the town centre and upstream of this they flow parallel to each other, with many sluice gates and channels allowing the transfer of water between the two rivers. These two Main Rivers present the only significant source of fluvial flood risk to the town. The extent of this risk has been studied by Halcrow, who completed a flood risk mapping exercise of the River Thet and Little Ouse in Thetford for the EA in 2006. The use of this modelling is described in Appendix C. No formal fluvial flood defences have been constructed in Thetford. Figure C.D1 shows the 1% flood outline and the watercourses studied.

Surface water flooding at several locations on the A11 has been reported by the Highways Agency. Some of this was due to blocked gullies. Anglian Water reported that sewer flooding occurred in the town centre at Bridges Walk in August 2006, and to the north of the town in Fairfields with a 2:10 years frequency.

There are five possible development sites in Thetford, four to the north and one to the south of the town. These are shown on Figure A.17.

Thetford

Figure A.17



A.4.1 Thetford Site 1 North

This possible residential development site is the biggest proposed development site located to the north of the town, between the current developed area and the A11 bypass road. It is presently arable farmland with some woodland. The land generally slopes from north to south, towards the currently developed land. A view of the development site is shown in Figure A.18.

Studying the OS mapping of this area and visiting the site has shown that there are no watercourses within the area.

This site is not considered to be at fluvial flood risk. However there is some history of surface water flooding on the A11 north of the site and some history of sewer flooding to the south of the site within the existing development. Development should be planned in a way which ensures that runoff from the A11 will not affect any new property, and that the new development will not exacerbate the sewer flooding of the existing development.

Properties at Risk:

None

Risk to Possible Development:

None

Access for Inspection:

Good, via Joe Blunt's Lane, Cedar Row, Norwich Road and Croxton Road.

Figure A.18: Thetford North Possible Development Site

A.4.2 Thetford Site 2 North-East

This is a small site which has been proposed for employment development. It is bordered to the north by the proposed development Site 1, to the south by the River Thet, to the west by the existing development, and to the east by Kilverston Hall. It is already partially developed with a garden centre. To the south of the site there is a lake.

The OS maps show that there are a few drains going through the site, however no flooding events have been reported.

According to the Thet flood mapping produced by Halcrow, the southern part of the site is at risk of flooding from the River Thet.

A.4.3 Thetford Site 3 North-West

This is a small site which has been proposed for employment development. It is bordered to the north by the A11, to the east by the proposed development Site 1, to the west by the A134 and to the south by the existing development. It is presently arable farmland.

According to the OS mapping of this area and to the site visits, there are no watercourses within the area. This site is not considered to be at flood risk.

A.4.4 Thetford Site 4 North-West

This is again a small site which has been proposed for employment development. It is bordered to the north-west by the A11, to the east by the A134, and to the south by the existing development. It is presently arable farmland.

According to the OS mapping of this area and to the site visits, there are no watercourses within the area. This site is not considered to be at flood risk.

A.4.5 Thetford Site 5 South-East

This possible residential development site is on the south eastern edge of Thetford. The Little Ouse River and the River Thet border it on its western and northern boundary respectively. The land is currently farmland – a mixture of arable and pasture used for grazing sheep and horses. The land rises steeply away from the rivers.

According to the Halcrow flood mapping study, only the River Thet poses a significant flood risk to the north border of the potential development site.

Apart from the flood risk from the Main Rivers, there are no further watercourses present in the possible development site.

Properties at Risk:

There are numerous properties considered to be at risk from flooding in Thetford due to flooding from the River Thet and Little Ouse.

Risk to Possible Development:

No development should occur within the River Thet floodplain (see Figure C:D1).

Access for Inspection:

Good, via the A1066 and A1088.

A.5 Watton

There are six separate possible development sites around Watton. The site to the east of the town is currently a derelict military base and disused airfield. The site is already fenced off in preparation for a residential development. Access to this site was a significant issue as existing buildings were being demolished. Four of the other five proposed sites are presently farmland and the site to the north west of Watton is presently Richmond Park Golf Course and farmland. The possible development sites are shown in Figure A.19.

Watton Brook, a Main River, borders the possible development site to the northwest of Watton. This was studied for the SFRA by constructing a hydraulic model using existing cross section survey. This is described in Appendix D. All six possible development sites also contain a number of unnamed drains. These were studied using the Level A mapping technique. The watercourses studied and the 1% flood outlines are shown in Figures C.E1 to C.E5.

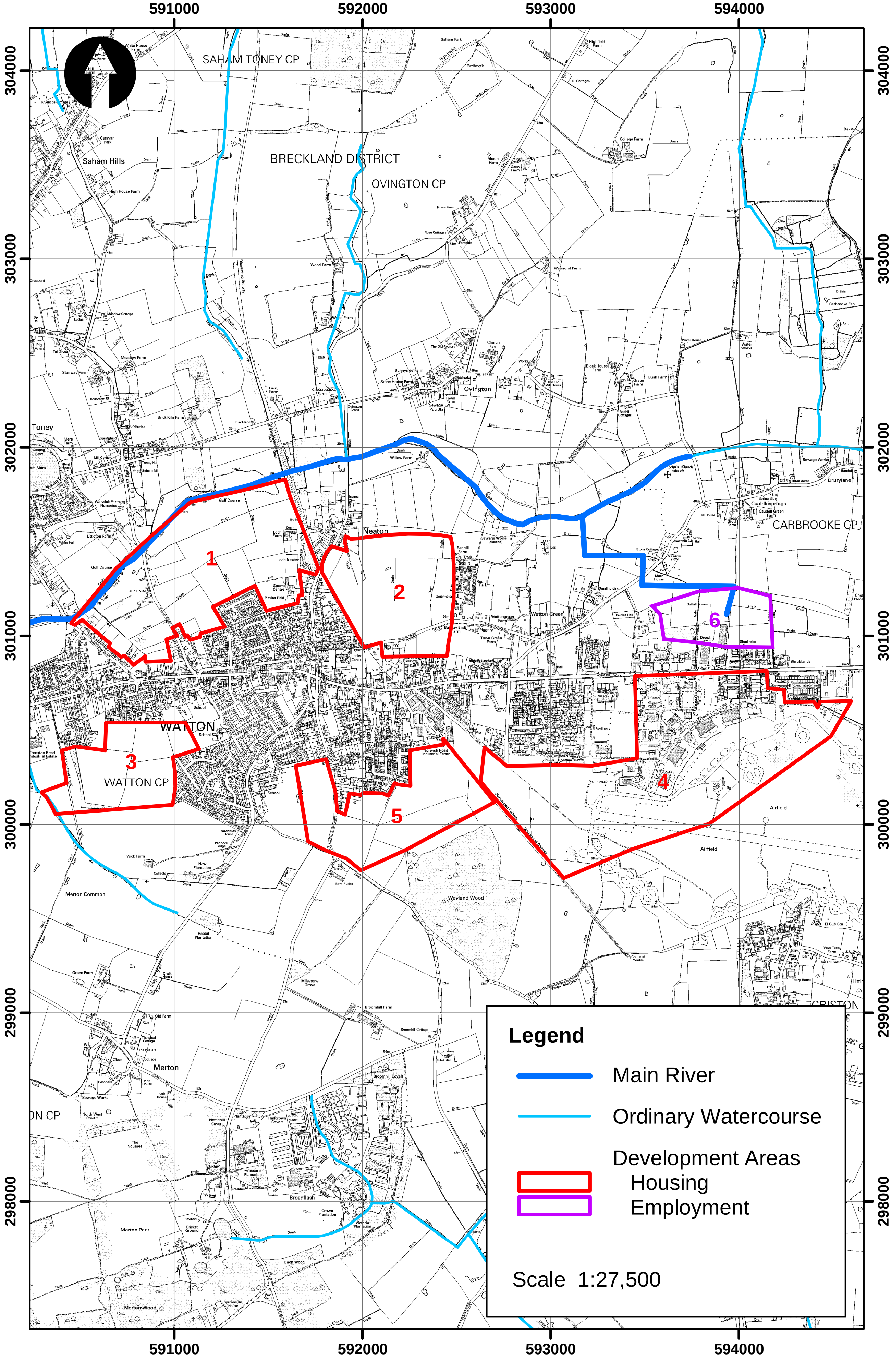
Surface water at the sites drains naturally away from the town of Watton.

- To the west, the site drains towards the ordinary watercourse Merton drain, before flowing into Watton Brook.
- To the north, the sites drain directly into the brook via a series of drainage ditches.
- To the east, the sites drain directly into the upstream section of the brook via a series of drains.
- To the south, the site drains into the ordinary watercourse Thompson Brook before eventually flowing into the River Wissey near Buckenham Tofts Park.

Anglian Water has reported several sewer flooding incidents throughout the town at Brandon Road, Swaffham Road, Saham Road, and Norwich Road.

Watton

Figure A.19



A.5.1 Watton Site 1 (Richmond Golf Course)

These watercourses were studied on 24 November 2004

This proposed residential development site is bordered by Watton Brook to the north and the town of Watton to the south. The site is presently occupied by a golf course close to the brook and grassland close to the town. The site slopes from south to north and contains a number of drainage ditches which flow into Watton Brook.

There is some history of sewer flooding to the west and south of the site at Swaffham and Saham Road respectively. It is recommended to examine this potential issue when undertaking more detailed studies for this site.

Nine watercourses in the golf course system have been studied. These are all Ordinary Watercourses flowing across Richmond Golf Course into Watton Brook. The reports on these watercourses are ordered, based on where they flow into Watton Brook, from upstream to downstream. All of these streams have similar characteristics, cleared banks with 45 degree slopes to the bed.

Richmond Golf Course OW 1

This drain is an ordinary watercourse on the border of the possible development site. It is a small ditch which flows along the base of the railway embankment. The length of the studied section is approximately 150m, from a drain forming the field boundary to the confluence with Watton Brook.

Channel:

The watercourse is shallow. The left bank 1.3m high while the right bank is over 3m high because of the railway embankment. There are no structures in the studied reach. The conditions of the channel remain constant throughout the studied section.

Floodplain:

Any flood risk would be limited by the small catchment and the railway embankment on the right bank.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that the risk of flooding to possible development is limited.

Access for Inspection:

Access via Richmond Golf Course.

Figure A.20: Richmond Golf Course OW 1 looking upstream

Richmond Golf Course OW 2

This drain is an ordinary watercourse outside of the possible development site. The watercourse is a small ditch which flows from Ovington Road in Saham Toney along a field boundary to Watton Brook. The length of the studied section is approximately 150m, from the edge of the golf course to the confluence with Watton Brook. The drain is shown in Figure A.21.

Channel:

The watercourse is initially shallow with vegetated banks. When it enters the golf course the banks have been cleared of vegetation and here the banks are steeper and slightly deeper, up to 1.5m.

There is one structure in the studied section. At the confluence with Watton Brook there is a 300mm diameter pipe culvert.

Floodplain:

Any flood risk directly from this drainage ditch would be limited by the small catchment and the extended channel.

The biggest risk of flooding comes from water backing up at the culvert when Watton Brook is in flood.

Existing Properties at Risk:

None

Risk to Possible Development:

This watercourse is between the possible development sites in Saham Toney and Watton, therefore there is a limited risk of flooding to the possible development sites.

Access for Inspection:

Access via Richmond Golf Course.

Figure A.21: Richmond Golf Club OW 2

Richmond Golf Course OW 3

This drain is an ordinary watercourse which flows perpendicular to Watton Brook in the upstream section and parallel to the brook in the downstream section. The upstream catchment slopes relatively steeply towards Watton Brook while the downstream section is in the floodplain.

The length of the studied section is approximately 480m.

Channel:

The watercourse is a drainage ditch, which starts flowing quite steeply towards Watton Brook. The channel is approximately 1.3m deep and 2.3m wide. There are two structures in the upstream section of the watercourse, both 300mm pipe culverts. At the time of study both of these were blocked by vegetation.

After the second culvert the watercourse follows the path of Watton Brook (Figure A.22). The channel starts with similar dimension as the upstream section, but gets deeper further downstream, reaching up to 1.75m before the confluence with Watton Brook. The banks of the channel get steeper as it gets deeper.

There are a number of small inflow pipes from the golf course throughout the studied area.

Floodplain:

There are a few main areas assessed to be at risk of flooding in a 1% flood event. Two are caused by water backing up at culverts which are partially buried and blocked by vegetation.

The third area at risk of flooding is on the left bank in the downstream section, although any flooding would be limited. This area however is in the floodplain of Watton Brook and most of the flooding would result from the Brook.

Existing Properties at Risk:

None

Risk to Possible Development:

As this drain is largely within the floodplain of Watton Brook it does not pose much of a separate flood risk.

Access for Inspection:

Access via Richmond Golf Course.

Figure A.22: Richmond Golf Club OW 3, flowing parallel to Watton Brook

Richmond Golf Course OW4

This drain is an ordinary watercourse which flows to the north of Watton Brook. The watercourse is a deep cut drain, starting off 1.75m deep and becoming deeper downstream. It is shown in Figure A.23.

The length of the studied section is approximately 575m.

Channel:

The watercourse is a drainage ditch, which flows along the boundary of the golf course. The channel is approximately 1.75m deep and 2.5m wide. There is no vegetation on the left bank while the right bank is heavily vegetated in places. The banks on the left are higher than those on the right bank.

At the time of study there was little flow in the upstream end of the watercourse. There are no structures in the studied section but there is a major inflow from Saham Toney Brook. Downstream of the confluence there is substantially more flow. A considerable amount of sediment, including large pebbles has been deposited at the confluence.

Between the confluence with Saham Toney Brook and that of Watton Brook the watercourse enters a wooded area where it is deep with steep banks.

There are a number of small inflow pipes from the golf course throughout the studied area.

Floodplain:

The area assessed to be at risk of flooding in a 1% flood event would be limited due to the small catchment and the deep cut of the channel. Any flooding that occurs will be restricted to the right bank.

The left bank is also at risk of flooding, but this would be from the Watton Brook. Although the right banks of Watton Brook are generally higher there is a ford in this section of the river, enabling flooding of the area.

Existing Properties at Risk:

None

Risk to Possible Development:

As this drain is largely within the floodplain of Watton Brook it does not pose a significant separate flood risk.

Access for Inspection:

Access via Richmond Golf Course.

Figure A.23: Richmond Golf Club OW 4 looking downstream

A.5.2 Watton Site 2 Neaton

These watercourses were studied on the 28 February 2005

This proposed residential development site is presently occupied by agricultural land situated in Neaton to the north of Watton. The site slopes toward Watton Brook from southwest to northeast and contains a number of artificial drainage ditches which eventually flow into the Brook.

Neaton Watercourse System

The Neaton watercourse system has been split into five sections to aid reporting. The studied watercourses in the possible development site are all connected. All of these watercourses have similar characteristics, in that they are drainage ditches with similar depths and bank slopes.

Channel 1:

This drainage ditch flows south to north in the centre of the possible development site; the studied section is approximately 220m, from the centre of the possible development site to the confluence with Channel 2.

The watercourse is a shallow drainage ditch (1.5m) with the left bank 200mm higher than the right bank. The conditions of the channel remain constant throughout the studied section.

At the Upstream end of the ditch is a 50mm diameter pipe discharging into the ditch; two other 50mm diameter pipes discharge further downstream.

Channel 2

This drainage ditch flows west to east from the confluence with channel 1 to the confluence with Channel 3. The studied section is approximately 300m. The Upstream end of the watercourse appears to have recently been culverted.

At the confluence with Channel 1 there is a discharge from a 100mm diameter pipe. In this location the left banks are slightly eroded and are 1.2m high; over the rest of the studied area the banks are 1.5m high on the left and 1.7m on the right.

There is one structure in the studied section; this is a partially blocked 200mm culvert.

Channel 3

The flow from Channels 1, 2, 4 and 5 all ends up in this channel. The channel is over 1.7m deep and flows from south to north for a small section before a sharp bend to the left and then to the right. The banks of the channel are always slightly higher on the left bank.

There is dense vegetation on either side of the channel with the blockages along the channel, especially at the sharp bends.

Channel 4

This drainage ditch flows along a track next to Redhill Park to the confluence with Channel 3. The channel initially flows from south to north but then flows from east to west after a small culvert section.

The watercourse is a shallow road ditch roughly 1.1m deep, with the left bank slightly higher. The conditions of the drain remain constant throughout the studied section. Close to Redhill Farm the watercourse enters a 200mm culvert, under a farm access bridge. The channel exits culvert next to Redhill Farm where the watercourse flows from east to west. The channel in this section is over 1.75m deep and 3m wide, 20m downstream of the culvert exit is the confluence of this channel with Channel 3.

Channel 5

This drainage ditch has similar characteristics to Channel 1; they both flow in the same direction, start at a culvert exit and have similar dimensions and catchment. This channel is however slightly different in that the channel enters a 100mm diameter culvert before discharging into Channel 2.

Floodplain:

The flooding from this watercourse system would be limited by the size and the slope of the catchment. All comment are based on the current artificial drainage system, which could be improved to further limit flooding in the area.

Flow from Channel 1 and the culvert at Channel 2 would combine to cause flooding at the upstream end of Channel 2, where the left bank is slightly eroded. There is a risk of flooding along the entire left bank of Channel 2 especially at the culvert which would restrict flow. Due to the slope of the catchment, flood waters once out of bank would not flow parallel to the channel but would flow northeast and collect in a low point close to Channel 3.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is a risk of flooding in the north of the possible development site from this watercourse system (See map). Although the flood waters would generally be shallow, there are a few areas where these flood waters will collect.

Access for Inspection:

Access via Redhill Farm.

A.5.3 Watton Site 3- Merton Common

This proposed residential development site is presently occupied by agricultural land situated on the outskirts of Watton. The site slopes gently from east to west toward the main watercourse in the area, Merton Brook.

These watercourses were studied on the 28 February 2005

Merton Brook

The studied watercourse is a Brook which runs around the south of Watton before flowing into Watton Brook, downstream of Watton Village. The studied section of the watercourse was from a plantation close to Wick Farm to the Threxton Road Industrial Estate, a length of approximately 750m.

Channel:

This brook flows to the south and east of the possible development site.

The upstream section of the watercourse is approximately 2.5m wide and 1.9m deep, with a 25cm high bund on the left bank. This embankment remains until 20m upstream of an arch footbridge which has its soffit 1.2m above the bed. The confluence with Long Bridle Ditch is immediately upstream of the footbridge, where there are two sharp bends in the channel.

Immediately downstream of the footbridge is a culvert which runs from a pond on the left bank. The culvert allows water to flow from the pond when nearly full. Downstream of the footbridge the right banks become lower than those on the left. The channel also becomes wider downstream of the footbridge, up to 5m wide in places, and deeper (2.2m). The conditions of the channel remain fairly similar to the end of the studied reach.

Floodplain:

The size of the watercourse means that there is a large risk of flooding from this watercourse. The extent of this flooding however would be limited due to shape of the valley in the upstream section, and large embankments in the downstream section. Flood water would however flow along Long Bridle Road.

Downstream of the footbridge there is a 2.5m high embankment which follows Long Bridle Road. This means that although the banks on the right are lower, flooding would be limited to one field.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is some risk of flooding to the possible development site, however this flooding is largely contained by embankments.

Access for Inspection:

Access via Long Bridle Road

Long Bridle Road Ditch

The studied watercourse is a Road ditch which runs along Long Bridle Road. A length of approximately 350m was studied.

Channel:

The Upstream section of the watercourse is a shallow drain along the un-surfaced road. Downstream of inflow from Wick Farm Drain the watercourse becomes slightly deeper, up to 1m deep upstream of the confluence with Merton Brook.

Floodplain:

The size of the watercourse means that any flooding would be limited to Long Bridle Road; downstream the flooding would be dominated by Merton Brook.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is limited risk of flooding to the possible development site.

Access for Inspection:

Access via Long Bridle Road.

Wick Farm Drain

The studied watercourse is a small farm drain which runs along a wooded area on Wick Farm. A length of approximately 150m was studied.

Channel :

The watercourse is a shallow drain along a forest area. There is one structure on the watercourse, a 100mm culvert which joins Long Bridle Ditch.

Floodplain:

The size of the watercourse and catchment means that flooding would be limited to the area around the culvert, caused by flow backing up at the culvert.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is limited risk of flooding to the possible development site.

Access for Inspection:

Access via Long Bridle Road.

A.5.4 Watton Site 4 Airfield Site

This proposed residential development site is presently occupied by an old airfield and barracks on the eastern fringe of Watton. Access to the site was very limited as demolition of the buildings on site had begun at the time. As the location of the open drains on the site is likely change in the near future, only watercourses downstream of the possible development site were assessed in this study.

These watercourses were studied on the 28 February 2005

Norwich Road Drain

The studied watercourse is a drain which runs from the possible development site to Watton Brook. The studied section of the watercourse was from Norwich Road to approximately 200m downstream. Although the upstream section of the left bank has been cleared there is a lot of debris and vegetation in the downstream channel.

Channel:

There are two 500mm diameter culverts which discharge from the possible development site into the drain. The drain itself is fairly small being 1.4m deep and 2m wide. Immediately downstream of the culverts there is an arch bridge under an access road, the bridge soffit is 1m above the level of the bed. Fifty metres downstream on the left bank is another 400mm inflow. There is one other structure in the studied section; this is a dilapidated arch bridge with its soffit 500mm above the level of the bed.

Floodplain:

The sizes of the culverts which discharge into this watercourse are too large for the capacity of the channel and other structures on the channel. The watercourse currently goes through an industrial estate where the left banks are slightly lower. It is assessed that most of the flooding would occur on this side and that the two buildings on the left bank will flood in the 1% flood event.

Existing Properties at Risk:

Two industrial buildings

Risk to Possible Development:

It is assessed that there is no risk of flooding to the possible development site, however discharge from the development site to this watercourse could cause flooding downstream of Norwich Road.

Access for Inspection:

Access via track

Hendon Avenue Drain

The studied watercourse is a drain which runs from the possible development site to Watton Brook. The studied section of the watercourse was from Norwich Road to approximately 100m downstream. Upstream the watercourse goes along the border of the possible development site and through an estate off Hendon Avenue.

Channel:

There are two 500mm diameter culverts which discharge into the upstream end of the studied section. One of the culverts comes from Hendon Avenue while the other comes from Norwich Road. The drain is 3m wide and 1.75m deep, there is housing on the left bank and a track on the right bank.

Floodplain:

The culverts which discharge into this watercourse are large for the capacity of the channel, but it is assessed that there would a limited amount of flooding from the watercourse. This flooding would be equal on both banks. It is assessed that the flood water would reach a shed on the right bank but would not reach the housing on the left bank.

Existing Properties at Risk:

Shed on right bank.

Risk to Possible Development:

It is assessed that there is no risk of flooding to the possible development site, however discharge from the development site to this watercourse could cause flooding downstream of Norwich Road.

Access for Inspection:

Access via track.

A.5.5 Watton Site 5- Norwich Road Industrial Site

This proposed residential development site is presently used for agriculture on the southern fringe of Watton. The site slopes gently toward the south west and contains a few drainage ditches. East of the possible development site is the site of a new housing development.

These watercourses were studied on the 28 February 2005.

A.1 Priory Road Drain.

The studied watercourse is a partially culverted drain which flows through the possible development site before entering culvert under the A1075. The studied section of the watercourse was from a culvert adjacent to 26 Priory Road to the A1075, a total length of approximately 725m.

Channel:

There are two 200mm diameter culverts which discharge into the upstream section of the drain. The upstream section of the drain borders properties off Priory Road. The drain in this section is very small, being 1m deep, with a slightly lower right bank. At the end of Abbey Road there is a partially silted 300mm diameter culvert under a disused farm access road. Downstream of the culvert the channel deepens to 1.3m with a slightly higher right bank.

The watercourse again enters culvert adjacent to 1 Abbey Road, this time the culvert is 400mm in diameter. The watercourse exits culvert in a small wooded area adjacent to 19 Abbey Road, the channel in this section is 1.2m deep with the right bank 500mm higher. Once out of the wooded section the bank heights are 1.4m and equal, these channel characteristics continue until the watercourse again enters culvert under the A1075.

Floodplain:

The size of the channel and catchment means that flooding from this watercourse would be limited. Although flooding would be limited at the upstream end of the watercourse, the lower right banks mean that some properties close off Priory Road are assessed to be at flood risk in the 1% event, these are numbers 10,12 and 24.

Two areas of low land adjacent to the watercourse are also assessed to be at flood risk in the 1% flood event, these are close to the A1075 culvert and the sharp right bend in the channel.

Existing Properties at Risk:

10,12 and 24 Priory Road

Risk to Possible Development:

It is assessed that the risk of flooding to the possible development site from this watercourse is low due to the limited size of the catchment.

Access for Inspection:

Access via footpath.

A.2 Thetford Road Drain.

The studied watercourse is a small road drain which flows along the border of the possible development site. Approximately 250m of the watercourse was studied.

Channel:

There are two culverts which discharge into the upstream end of the studied section; these are 300mm and 100mm in diameter. There are two additional inflows 100m downstream.

The drain starts at 1.4m deep but quickly increases to 1.75m deep. There is a 25cm bank on the right next to Thetford Road. There are three 200mm diameter culverts in the studied section spaced roughly 50m apart.

Floodplain:

It is assessed that there is a low risk of flooding from the watercourse due to the size of the catchment. Any flooding would be on the left bank, with the greatest amount of flooding caused by flow backing up at the culverts.

Existing Properties at Risk:

None

Risk to Possible Development:

It is assessed that there is a small risk of flooding to the possible development site from this watercourse.

Access for Inspection:

Access via Thetford Road.

A.5.6 Watton Site 6- Blenheim Court Site

This small proposed employment development site is located just north of the Norwich Industrial Estate, and off the existing Blenheim Court residential development. It is presently occupied by agricultural land. The site contains a few drainage ditches, which eventually flow into the Watton Brook. There is no recorded history of flooding from these ditches.

Appendix B: Flood Risk Assessments for Larger Villages

This section details each of the larger villages which are proposed to accommodate some development. It documents the available data, describes the methodology specific to each site for delineating the flood zones and observations are made on the level of flood risk to each village.

The possible development areas in each village were identified by placing a 250 metre buffer around the village.

No previous flood studies have been undertaken for the larger villages.

The watercourses studied and the 1% flood outlines for each village are provided as fold out maps in Appendix C.

B.1 Banham

This village was studied on 26 January 2005.

Banham is located in the headwaters of the River Wittle, a tributary of the Thet. The watercourses were studied using Level A mapping. They are shown in Figure C.F1.

B.1.1 Wash Farm Stream

Wash Farm Drain rises adjacent to Wash Lane to the south of Banham and flows in a northerly direction along the western side of the village.

Channel and Floodplain:

Alongside Wash Lane the ditch is overgrown and fast-flowing. It is 0.6 metres wide at the normal water surface and 2 metres wide and 0.5m deep at bankfull. The stream is culverted for access to Wash Farm and Treetops with 0.5 m square culverts. These are likely to block in flood conditions; however, flooding will be limited to Wash Lane.

At Kenninghall Road the stream flows under a brick arch bridge which is about a metre wide. Upstream of the bridge is a small weir with a drop of around 0.2 metres. This will be drowned out during medium-high flow conditions. The channel is 1-2 metres wide and flooding in this location will be limited. It is possible that water may spill over the bridge onto the road, however the gradient will mean this water will drain down the road to the east and not rejoin the stream.

Downstream of Kenninghall Road the stream is very overgrown and the banks are in a poor state of repair, partially due to ongoing housing development. The channel is about 1.5 metres wide and the 1% event is considered to remain within the banks. Development is occurring on the left bank at this location.

The stream passes under a small footbridge. At this location the channel is 0.8 – 1.0 metre wide and the banks are 0.4 metres high. Water will spill out-of-bank and flood an area about five metres wide.

For the next 400 metres the stream is confined within a high banked ditch. The banks are approximately two metres high. Although the ditch is overgrown, the large channel capacity and relatively steep gradient means that in a 1% flood event water is likely to remain within the banks.

The nature of the stream then dramatically changes from oversized, steep ditch to a more natural, shallow gradient channel with a well-defined floodplain. The channel is shallow and wide, probably due to grazing animals and the floodplain is wet and marshy. It is 5-6 metres wide and 0.5-0.8 metres deep at bankfull. In the 1% flood event it is anticipated that a wide expanse of land will be flooded. This area is shown in Figure B.1.

Figure B.1: Wash Farm Stream, looking upstream from Church Hill Bridge

The stream passes under Church Hill Bridge through a 0.8 metre diameter pipe culvert. There is a weir immediately downstream of the bridge with a 0.3 metre headloss. Drainage from the road enters the stream upstream of the bridge. During the 1% flood event flood water will pass across the road.

Downstream of the road the channel is 2 metres wide and 1 metre deep. The land on the left bank is at a higher elevation that the right bank, therefore flooding will be confined to the right floodplain in this area.

Existing Properties at Risk:

None

Risk to Possible Development:

Development would be at risk of flooding if sited on the low-lying land downstream and upstream of Church Hill Bridge. This land is within the 1% floodplain shown on Figure C.F1.

Access for Inspection:

Wash Lane, Kenninghall Road and footpath on the left bank of the stream.

B.1.2 Church Farm Stream

Church Farm Stream is a tributary of Wash Farm Stream, the two streams joining to the north west of the village. It rises behind Church Farm and flows in a north easterly direction. It flows through pasture and meadow land. It is shown downstream of the footpath from Church Hill in Figure B.2.

Figure B.2: Church Farm Stream, downstream of footpath crossing

Channel:

The stream is about 0.5 metres wide with 1 metre high banks. There are several culverts along the watercourse that allow tracks and paths to cross the watercourse. These will all be readily bypassed during flood events and therefore backing up of water due to blockage will not be a major issue.

Floodplain:

In the village the stream will flood land on the lower right floodplain in the 1% flood event. Further downstream the lower left floodplain will be inundated in the 1% flood event.

Additional Information:

Informal discussion with a local resident of 13 years on the footpath from Church Lane through to Greyhound Lane. She could not recall any flooding incidents.

Properties at Risk:

None

Risk to Possible Development:

Development is not advised if sited on the land within the 1% floodplain as shown on Figure C.F1.

Access for Inspection:

Via footpath and Church Hill.

B.2 Great Ellingham

This village was studied on 26 January 2005.

Great Ellingham is located in the headwaters of the River Thet. The only watercourses identified within the village are the drains adjacent to Penhill Lane, which is shown in Figure C.G1, and the drain which runs along Long Street. Breckland District Council reported that localised surface water flooding occurred in Long Street due to the lack of maintenance and/or lack of capacity of the drain. Level A Flood Mapping has not been carried out for this drain due to its very small size.

B.2.1 Penhill Lane Drain

The drain was studied for a length of 400 metres. It drains fields on the edge of the village and flows adjacent to the road down a steep gradient. The fields on either side of the road are at a higher elevation and the drain is unlikely to spill out-of-bank due to the gradient. It is shown in Figure B.3.

Figure B.3: Penhill Lane Drain adjacent to the road looking downhill

The ditch continues to flow alongside the road, under the front entrance to many properties through culverts around 0.3 – 0.4 m diameter. Some new properties have been recently constructed downstream of the junction with Town Green and the drain has been culverted through a 0.4 m diameter pipe at this location. It is evident that this has affected road drainage as downstream of the pipe someone had recently hand dug a drainage channel from the edge of the road to the ditch. They had also recently dug out the drain, meaning that flood risk in this area is thought to be minimal.

Properties at Risk:

None.

Risk to Possible Development:

None.

Access for Inspection:

Via Penhill Lane.

B.3 East Harling

East Harling was visited on 13 January 2005.

The River Thet flows along the western edge of East Harling. A steady-state hydraulic model has been created from existing cross section data for a 2 km reach of the Thet. This is detailed in Appendix D.

East Harling generally drains from east to west down towards the River Thet. However, the northern edge of the village drains to a low area to the north of the village before entering the Thet and the southern edge of the village drains south to join a tributary of the Thet.

Several drains on the northern and southern edge of East Harling have been assessed in terms of flood risk using the Level A flood risk mapping approach. Fen Lane Drains near White Bird Farm were studied. Garboldisham Road Drain was assessed and the Forest Lodge and Mauley's Drain was studied near West Harling Road. No access was obtained to the upstream end of Mauley's Drain. A total of 1.4 kilometres of drain were studied. These are shown in Figure C.H1.

B.3.1 Fen Lane Drains

These have a small catchment area and are unlikely to pose a significant flood risk, although the fields they flow through had wet areas adjacent to the drains. Due to the topography, a greater flood risk to this area is likely to originate from the River Thet which will readily spill into the low lying wetland area to the north of the village and could cause backing up of the two drains.

Additional Information:

Informal discussion with a resident of Fen Lane for 41 years. He knew of no specific flooding issues from the drains, but said that flood water from the River Thet comes up into the area, but the properties on Fen Lane had not been flooded.

Existing Properties at Risk:

None

Risk to Possible Development:

Development is not advised within 10 metres of these drains.

Access for Inspection:

These drains were accessed via Fen Lane.

B.3.2 Garboldisham Road Drain

This drain was dry at the time of the field visit. It was very overgrown and there had been no water in it for any period of time in the recent past. It was about 1 metre deep and 4-5 metres wide. There were no obvious piped inflows. This drain is highly unlikely to pose any significant flood risk.

B.3.3 Mauley's Drain

This watercourse drains the southern edge of East Harling. Upstream of West Harling Road the channel is 1.5 metres wide and 1.5 m deep at bankfull. The land use on both banks and further upstream is pasture. The ditch is wooded on both banks and overgrown. The drain passes under the road in a 1 metre diameter pipe culvert (Figure B.4). This is susceptible to blockage and will cause water to spill out of bank onto the left floodplain upstream of the road. In the 1% flood event water is unlikely to spill across the road as it is higher than the surrounding land.

Figure B.4: Mauley's Drain showing upstream end of Culvert under West Harling Road

Downstream of the road the watercourse flows across a meadow to join the River Thet. The gradient of the stream is shallow, therefore it is likely that the drain will back up during high flows on the Thet. The drain is 1.5 metres wide and the banks are 1.5 – 2 metres high at bankfull. The banks and the land levels are generally lower on the left bank, meaning that flooding will occur on the left floodplain.

Existing Properties at Risk:

None

Risk to Possible Development:

Development is not advised within 10 metres of this drain.

Access for Inspection:

Limited access via West Harling Road.

B.3.4 Forest Lodge Drain

This drain runs parallel to Mauley's Drain upstream of West Harling Road. As it meets the road it turns through ninety degrees and runs alongside the road for 10-15 metres. The drainage path indicates that it should then discharge into Mauley's Drain immediately upstream of the road culvert. However, it appears that a field entrance has recently been constructed/rebuilt across the drain. This entrance contains no culvert for water to pass from Forest Lodge Drain into Mauley's Drain and hence on to the River Thet.

This blockage is considered a serious obstruction and will cause flooding of the field between Mauley's Drain and Forest Lodge. However, at the time of the field visit the drain was generally dry, with some standing water adjacent to Forest Lodge. However, the muddy nature of the bed and banks indicated that water levels have recently been higher in this location.

The channel is 2-3 m wide and 1 m deep at bankfull. It is very overgrown.

Existing Properties at Risk:

None

Risk to Possible Development:

Development is not advised within 10 metres of this drain.

Access for Inspection:

Limited access via West Harling Road.

B.4 Mattishall

Mattishall was visited on 12 January 2005.

Mattishall drains from south to north towards the River Tud, which is located approximately 1.5 km north of the village. Cross sectional survey has been undertaken along this reach and therefore a steady-state hydraulic model has been constructed to determine flood risk. This is described in Appendix C.

There are two main tributaries of the River Tud which flow through Mattishall. The most easterly, Jacob's Island Drain, could not be accessed, except at Watercress Lane, on the outskirts of the village. The Moat Stream flows through the centre of the village from north to south. A tributary of this stream – Occupation Road Drain – was also studied.

A total length of 1.3 km of watercourses was studied using the Level A fieldwork technique in Mattishall. These are shown in Figure C.I1.

B.4.1 Moat Stream

This watercourse flows from north to south through the centre of Mattishall. Upstream of the village the stream flows through arable land near Lime Tree Farm. In this area several field drains combine to form the main stream which then flows behind the properties on Willow Close. The field drains are all small with steep gradients. Water will not spill out of bank in the 1% flood event except for into the gardens of the properties on Willow Close as the gardens are lower than the field on the right bank.

Further downstream at the top of Cedar Rise the channel still has a steep gradient. Flow in the stream was 0.4 metres wide and less than 0.03 metres deep. The bank is approximately 1 metre high on the right bank and 0.8 m high on the left bank, meaning that during the 1% event water will spill into the back gardens of the properties on Willow Close.

The stream then flows through a steep wooded valley. The stream is constrained on both sides by residential properties, but the steep channel and well defined valley will mean that there is no flood risk to property along this reach.

The stream then passes under Dereham Road through a brick arch bridge which is approximately 1.2m wide and 0.6 m high (Figure B.5). There was minimal flow in the stream, the water surface being just 0.3 m wide. The channel is 1.5 – 2 metres deep at bankfull and around 5 metres wide. Upstream of the bridge the stream is unlikely to exceed bankfull due to the steep channel gradient. However, the fact that road drainage enters the channel upstream of the bridge and the limited bridge opening, means that the bridge is susceptible to blockage. This will cause water to spill onto Dereham Road.

Downstream of Dereham Road the stream flows through the gardens of several houses. The channel has a lower capacity than upstream of the bridge, being about 1.5 metres deep and 3-4 metres wide at bankfull. The channel gradient is also shallower and the stream is overgrown. The left bank of the stream is lower and this will mean that gardens of the properties on the left bank are at a risk of flooding.

Further downstream the stream passes Bob Carter Court, a sheltered residential home. At this location the channel has similar dimensions to just downstream of Dereham Road. This is situated on the left bank. On the right bank is open pasture, characterised by archaeological remains of a moat. This means that the topography of the right bank has been modified, resulting in the right floodplain being extensive in this location.

The drain then continues in a northerly direction, with similar dimensions and degree of flood risk to further upstream.

Figure B.5: Moat Stream looking downstream to Dereham Road Bridge

Existing Properties at Risk:

None

Risk to Possible Development:

Development is not advised within 20 metres of this stream.

Access for Inspection:

Access via path from Cedar Rise/Weigate Road, Dereham Road and Bob Carter Court.

B.4.2 Occupation Road Drain

This small drain is a tributary of the Moat Stream. It flows from Burgh Lane alongside Occupation Road and then across an arable field to join the Moat Stream.

Alongside Occupation Road the drain is 2-3 metres wide and around 1 metre deep at bankfull. The channel had recently been cleared of vegetation. There were a number of piped culverts along this length to allow vehicular access to houses and fields. These culverts have a diameter of 0.3 m and are highly susceptible to blockage. The home owner at the property on the right hand side at the end of Occupation Road said that the water had recently spilled out of the drain, onto the road and into their front garden. This was attributed to a blockage in one of the culverts, but the capacity of the culvert could also have been readily exceeded.

At the end of Occupation Road the drain passes through another 0.3 metre diameter drain that is also liable to cause flooding to Occupation Road. This is shown in Figure B.6. On exiting the culvert the drain follows a field boundary. It has a smaller capacity than further Upstream and is more overgrown. Therefore, water is likely to spill onto the field on the lower left bank in the 1% event.

Figure B.6: Occupation Road Drain looking downstream

Existing Properties at Risk:

Bungalow on Occupation Road.

Risk to Possible Development:

Development is not advised within 10 metres of this drain.

Additional Information:

Informal discussion with the home owner of the property on the right hand side at the end of Occupation Road said that the water had recently spilled out of the drain, onto the road and into their front garden. This was attributed to a blockage in one of the culverts, but the capacity of the culvert could also have been readily exceeded.

Access for Inspection:

Good access via Occupation Road.

B.5 Narborough

This site was studied on 25 November 2004 and 1 March 2005.

The sites around the village are presently occupied by agricultural land and playing fields. The northern end of the Narborough lies on the River Nar. The river has been diverted and divided to supply two disused mills. Although disused, a complicated series of sluice gates and weirs still exist.

The principal watercourse impacting on the site is the River Nar. There are also several ordinary watercourses. They were all mapped using the Level A technique.

Surface water at the site drains naturally towards the River Nar, either directly or via a series of drains. The village is within an IDB area operated by the Kings Lynn Consortium.

B.5.1 River Nar

The River Nar is classified as a Main River downstream of the village of Narborough. In the village the river is an IDB drain under the management of the Kings Lynn Consortium. The River Nar in Narborough is a complex system, where the channel divides into two main channels originally to supply two large mills. There are also numerous other minor channels used to supply running water to ornamental and fishing lakes.

The length of the studied section is approximately 280m, from upstream of the A47 to the confluence of the two channels downstream of Narborough. The watercourses studied are shown on Figure C.J1.

Channel:

The watercourse is classified as Main River at the downstream limit of the studied area, and is a similar size at the upstream extent of the study, before the watercourse splits to supply the mills and lakes.

Upstream of the A47 the watercourse flows through a forested area, where the channel is wide and shallow. The banks on the left are slightly higher; however there is a raised embankment on the right 5-15m from the channel which is approximately 2m high. There is also an overflow channel on the right bank which is connected to the channel by a 300mm diameter pipe culvert. The overflow channel goes into fishing lakes on the other side of the embankment. This is shown in Figure B.7.

Under the A47 there is a large bridge, 3.5m wide, which should not substantially restrict flow. Downstream of the bridge the channel splits into two; the slightly larger channel (Channel A) goes off to the left while the other channel (Channel B) maintains the original course.

Channel A:

This sub-channel is approximately 2.3m wide and is the same depth as the upstream section. The banks are approximately at the same level however the left bank is in poor condition. In a conversation with the owner of the fish farm it was noted that the bank has been close to breaching and that boards were placed along the bank to stop the water.

Below the left bank there is a drop of 2m and a culvert which takes spring water under the river into the fish farm. A breach at this location would divert the majority of the river flow through the fish farm.

Figure B.7: Overflow Channel from River Nar into Fishing Lakes

The banks downstream of this point are very low, less than 30cm above the level of the water at the time of study. The level of the river in this section is managed by a sluice gate located at a downstream mill. There are two outflows to drains which flow through the fish farm, both have trash screens.

There are two sluice gates at the mill only one of which was open at the time of study. Water flowing through the fish farm rejoins the river channel downstream of the sluice via a 500mm pipe culvert. This drain acts as an overflow drain and the inflow is controlled.

Downstream of the mill there is a small pond before a slab bridge under Main Road, the soffit is 1.9m above the bed level, and is shown in Figure B.8. The watercourse between the bridge and the confluence with channel B is wide and shallow, with high banks. The banks on the right are approximately 1.5m high with those on the left higher still.

Figure B.8: Main Road Bridge, Narborough showing Mill Upstream (Channel A)

Channel B:

This sub-channel is approximately 2m wide but deeper than the upstream section. The watercourse is very slow moving and straight, it has the same dimension from where the channel splits to Main Road.

The water level in this section of the watercourse is controlled by a weir and sluice gate upstream of Main Road. The banks of the watercourse are approximately 50cm above the level of the water.

The watercourse lies above much of the land on the left bank which includes a fish farm and a car yard. On the right bank there is an embankment which runs the length of the studied section. On the other side of this embankment is another watercourse with similar channel dimensions to Channel B. The channels run in parallel up to Main Road where both channels are in culvert, downstream only Channel B is visible after Main Road.

There is a weir and sluice gate 10m upstream of an arch bridge under Main Road, between the two structures both banks are reinforced with bricks (Figure B.9). Downstream of the road bridge there is another weir and sluice gate. The watercourse has steep banks and passes through a disused mill building 50m downstream of the weir. Downstream of the mill the watercourse becomes deeper before Channel A rejoins (Figure B.10).

Figure B.9: Weir on Channel B adjacent to Mill

Figure B.10: Confluence of Channel A (right) and Channel B (left) looking downstream

Floodplain:

The floodplain for the River Nar in and around the village of Narborough has been modified greatly by the addition of flood embankments, diversion of the river and structures placed on the river.

Upstream of the A47 flood water would be channelled into nearby ponds, but would also flood fields on the left of the watercourse. The A47 bridge is large and would not restrict flow.

The main area that flooding could affect is downstream of the A47 between the two channels. The water level in the upstream area is controlled by a number of old sluice gates. Water backing up at these sluice gates would flood the area between the two streams. At the moment this is the site of a fish farm. In a worst case scenario the channel banks would breach and a large proportion of the flow would go down the centre of the fish farm across Main Road rejoining the main channel downstream.

Existing Properties at Risk:

Industrial Estate on the site of old mill on Channel B.

Risk to Possible Development:

It is assessed that there would be significant flood risk to any development close to or between the two channels of the River Nar. It is assessed that there is a high risk of flooding in these areas especially upstream of Main Road. This is a consequence of aging sluice gates and erosion of the river banks.

Access for Inspection:

Access via public footpath (Nar Valley Way) on right bank. Also via the fish farm and industrial area.

B.5.2 Butlers Drain:

This watercourse is a drain which flows to the south west of Narborough village, into the River Nar. It is a relatively large ordinary watercourse, which flows through agricultural land and forested land, the path of the watercourse appears to have been slightly altered in the agricultural land.

The length of the studied section is approximately 700m from Butler's Barn to the confluence with another drain near a sewage works.

Channel:

The watercourse is a drainage ditch which is approximately 1.8m deep adjacent to Butler's Barn, at this point both of the banks are clear. The channel conditions remain the same until a 500mm diameter culvert under Meadow Lane. Downstream of the culvert the channel takes on a more natural appearance and becomes 200mm deeper and over 1.5m wider. The drain enters a forested area before flowing through a 500mm diameter culvert under Meadow Track.

Downstream of this culvert the left bank remains forested while there is agricultural land on the right bank. The channel has become partially blocked (See photo) by tree branches, at the time of study the water was backing up to the culvert under Meadow Lane.

At the confluence with Allotment Drain (see report below) and another drain the studied watercourse becomes slightly wider.

The sewage works does discharge into the watercourse however there was no access to the outfall and no information regarding consented discharges is available.

Floodplain:

It is assessed that due to the size of the catchment and the susceptibility for blockages in the channel especially at the culvert there is the potential for flooding from this watercourse. Flooding would occur on both banks but areas close to the culverts would be particularly susceptible.

Existing Properties at Risk:

None.

Risk to Possible Development:

It is assessed that no development should occur close to this watercourse due to the large risk of flooding.

Access for Inspection:

Access via Meadow Lane and Meadow Track.

B.5.3 Allotment Drain

This watercourse is a drain which flows from Narborough village to Butler's Drain. It flows through agricultural land and an allotment on the edge of Narborough. The agricultural land surrounding the drain has poor drainage, with most of the water collecting in local depressions rather than in the drain.

The length of the studied section is approximately 400m from the allotments to the confluence with Butler's Drain.

Channel:

In the upstream section the watercourse is a drainage ditch drainage ditch which is approximately 1.8m deep and 3m wide, with trees along both banks. The channel conditions remain the same until a culvert under a farm access track, there was not access to the culvert. Downstream of the culvert the channel becomes 200mm deeper and initially over 1.5m wider after the culvert both banks are clear however there are reeds in the channel.

Upstream of the confluence with Butler's Drain the channel becomes narrower.

Floodplain:

It is assessed that due to the size of the catchment and channel capacity the potential for flooding from this watercourse is low. There is however one low area on the right bank downstream of the culvert which is assessed to be susceptible to flooding in the 1% flood event.

It is possibly that the area of upstream flooding could be greater due to blockages at the culvert.

Existing Properties at Risk:

None.

Risk to Possible Development:

It is assessed that there is a limited flood risk to the possible development site from this watercourse. The largest risk of flooding occurs on the right bank close to the confluence. The drainage of the whole area would need to be improved to reduce the risk of flooding from rainfall build-up.

Access for Inspection:

Access via Meadow Track.

B.6 Necton

Necton was studied on 1 March 2005.

Necton is located to the north of the River Wissey. At this point the river is about 2 metres wide and the floodplain is not well defined. No modelling has previously been carried out for this section of the River Wissey. There are cross section surveys at 200m spacing available and these were used to create a hydraulic model for a 3 km reach. This is detailed in Appendix D.

In addition to the Wissey, there are several ordinary watercourses around the village. These were studied using the Level A mapping technique. The watercourses studied and the 1% outlines are shown in Figure C.K1.

The full area of Necton drains either directly, or via a series of drains, from north to south into the River Wissey.

The Lynn News reported that sewage polluted flood water was threatening bungalows in Chantry Lane, Chantry Court and Mill Street following a torrential rain on Monday 29 June 2007. The flooding seems to have originated from several sources. There was some surface water flooding due to blocked drains, fluvial flooding due to a blocked culvert of the Necton Brook in Chantry Lane, and sewer flooding due to a manhole cover being lifted in Chantry Lane.

The Highways Agency reported that surface water flooding occurred on 12 August 2004 on the A47 to the north of the village.

B.6.1 Necton Brook

This is an ordinary watercourse which flows along the A47 before flowing through the centre of the village and then joining the River Wissey. There is some history of flooding of the Necton Brook due to the Chantry Lane culvert which is prone to flooding.

It was not possible to get access to the brook in the centre of the village therefore the study concentrated on the sections on the outskirts of the village. The length of the studied section is approximately 1500m, from the A47 to the confluence with the River Wissey, this length excludes the section in the middle of the village.

Channel:

The upstream section of the watercourse is a deep cut drainage ditch. There is a 500mm diameter culvert in this section with a 500mm diameter outfall 10m downstream. This outfall comes from a channel on the other side of the A47. Downstream of the inflow the channel gradually becomes shallower, and is only 1.4m deep by the time the channel enters a further 500m culvert (see photo). An number of earth mounds on the right bank would limit any flooding, however these earth mounds are not present where the channel enters the culvert.

The second studied section of the watercourse was from St Andrews Lane to School Road. The watercourse exits culvert just upstream of St Andrews Lane (Figure B.11), before immediately going under an arch bridge with a 1.4m soffit above the river bed. The channel immediately downstream of the arch bridge is deep and wide; however the channel dimensions quickly change to 1.5m deep with steep left banks. The characteristics of the channel remain similar as the watercourse flows through an arch bridge under School Road with a 1.4m soffit above the river bed. There is a distinct slope toward the watercourse on the left bank, whereas the land on the right bank is flat.

The third reach studied is from a culvert under Chantry Road to the confluence with the River Wissey. The watercourse flows under Chantry Road via an arch bridge with its soffit 1m above the river bed. The channel in this section is 1.5m deep with shallow slopes on the banks. By the time the channel reaches a 1m diameter culvert under Hale Road the channel has become over 1.8m deep. Downstream of the culvert the channel has similar dimensions but becomes slightly deeper and over 2m wider downstream of the confluence with another drain. Just upstream of the confluence with the River Wissey there is a small footbridge over the channel, this footbridge has a soffit 1.8m above the river bed.

Floodplain:

It is assessed that there is a risk of flooding from this watercourse along all of the studied section. This flooding would be greatest at the restrictive culverts upstream of St Andrews Lane and at Hale Road. It is assessed that in the upstream section of the watercourse the extent of flooding will limited in extent due to the gradient of the valley, with most of the flooding occurring on the right bank.

In the section between Chantry Lane and the confluence with River Wissey the land is a lot flatter and flood waters would cover a large area in a 1% flood event.

Existing Properties at Risk:

In Chantry Lane.

Risk to Possible Development:

It is assessed that there is a risk of flooding to possible development from this watercourse, downstream of Hale Road this flooding would overlap the floodplain of the River Wissey.

Access for Inspection:

Access via farm access track.

Figure B.11: Culvert near St Andrews Lane

B.6.2 Necton Drains

To the west of Necton there are a number of large field drains, which are shown to present a potential flooding risk in the EA's flood zone maps. These are all field drains, which eventually discharge into the River Wissey. All drains in this system have similar characteristics.

The total length of the studied section is approximately 1000m.

Channel:

These watercourses are deep cut drainage ditches which are all approximately 2m deep and 4m wide. The conditions of the channel remain constant for most of the studied section; however the channel does become slightly wider close to a track. There is one structure in the studied section of drains; this is a 750mm diameter culvert under the track (Figure B.12).

Floodplain:

Although the drains do have a relatively large capacity, it is assessed it is not sufficient for the combined catchment of these drains. Flooding from these drains alone would be shallow and occur on both banks. If the flood event for these drain coincides with flooding on the River Wissey this flooding would be of a greater depth.

Existing Properties at Risk:

None.

Risk to Possible Development:

It is assessed that at present these watercourse are all at risk of flooding in the 1% flood event. The gentle slope of the land in this area combined with the density of drains means that most of the surrounding agricultural land is assessed to be at risk of flooding in the 1% flood event.

Access for Inspection:

Access via track.

Figure B.12: Culvert under Farm Track

B.7 North Elmham

North Elmham was studied on 12 January 2005.

Wendling Beck (Black Water) flows into the River Wensum on the eastern edge of North Elmham. Both these rivers were modelled by Babtie, Brown and Root in 2003 and flood levels for the 1% and 10% flood have been taken from this work.

In addition, there is an ordinary watercourse, Town Beck, which flows through the village. This watercourse also has a number of drains feeding into it. This system was assessed in terms of flood risk using the Level A mapping approach. A total of 1.6 kilometres of watercourses were studied in this way. They are shown in Figure C.L1.

The full area of the village of North Elmham drains into Town Beck which flows from north west to south east and enters the River Wensum on the outskirts of the village at Mill House Farm.

B.7.1 Town Beck

Town Beck flows in a south easterly direction through the village before entering a network of drains on the River Wensum floodplain. This drainage network discharges into the River Wensum near Mill House Farm.

Upstream of Holt Road the beck flows through Elmham Park. Around 250 metres upstream of Holt Road the OS mapping shows a lake in Elmham Park. This appears to be ornamental and is assumed to be kept full. The small surface area of the lake means that it will have negligible impact on attenuating flows in the stream.

Between the lake and Holt Road the stream flows through grass parkland. Immediately upstream of Holt Road there is a property (Wellesley House) on the right bank with a garden leading down to the beck. The bridge under Holt Road is of brick arch construction, approximately 1.5 metres wide and 1 metre high. It will constrict flow in the 1% event leading to water spilling onto the left bank floodplain upstream of Holt Road. Adjacent to Holt Road a brick wall will retain flood water, but may be undermined in a high flow event. Wellesley House is unlikely to be affected in the 1% event.

Downstream of Holt Road Town Beck flows alongside North Elmham Primary School. Adjacent to the school buildings the channel is 1.5 metres wide at the normal water level and at bankfull the channel would 3-4 metres wide and 1.5 m deep. A wall adjacent to the channel on the right bank will mean that at this location the left bank (property gardens) is more susceptible to flooding. The Head Teacher at the Primary School had no recollection of high water levels on the beck.

Approximately 50 metres downstream of Holt Road a tree trunk has formed a natural weir across the channel. It appears that this trunk has been in place for a considerable period of time. Water drops approximately 0.4 m over this weir.

A new footbridge has been installed over Town Beck 100 metres downstream of Holt Road (Figure B.13). At this point the channel is wider and shallower due to access to the channel for animals to drink. The bridge has potential to cause a blockage during high flows due to the assorted materials the farmer has fixed to the underside of the bridge to try and contain the animals.

Figure B.13: New School Footbridge over Town Beck

The channel flows behind the houses on Brookside. The channel has been narrowed by the homeowners so that it is approximately one metre wide and a small bridge has been added in one garden. Due to the constriction formed by the culvert further downstream under Cathedral Road, it is probable that the 1% flood will cause some flooding to the properties on Brookside backing onto the river. Some of the school playing field is also at flood risk.

The beck passes under Cathedral Road in a 1 metre diameter pipe culvert. This will form a restriction in the 1% event and water will back up behind the road and flood properties on either bank upstream. On the downstream side of Cathedral Road the beck flows between houses on Brookside and those on Larch Grove. The channel is well maintained and approximately 1 m wide. The resident of No. 30 Cathedral Road informed us that in autumn 2000 the beck had reached the top of its banks, but she knew of no flooding to property in the village.

Town Beck then flows across open pasture land behind houses on Eastgate Street. None of these properties are considered to be at risk of flooding from the beck. The channel is 2-3 metres wide along this reach and the floodplain is difficult to define.

A track crosses the beck near Old Hall Farm. The water passes under the track in two parallel 0.25 metre diameter pipes. The capacity of these pipes will often be exceeded; however the water will freely flow over the track, so blockage of the pipes will not cause an increase in flood risk.

Downstream of the track crossing, the beck flows under the Mid Norfolk Railway. This is on an embankment, approximately 1.5 metres above the surrounding floodplain. The floodplain is shown in Figure B.14. The beck passes under the railway in a 0.4 metre diameter pipe. This will greatly restrict flow causing water to spill onto the floodplain upstream of the railway. In the 1% event water will spill into a low point on the left floodplain where there is an access tunnel under the railway. This tunnel will act as a flood culvert during the 1% event. There was no access downstream of the railway, therefore the floodplain may continue beyond the area currently shown.

Figure B.14: Town Beck looking upstream from Mid Norfolk Railway embankment

Existing Properties at Risk:

Properties on Cathedral Road, including No. 30.

If not mitigated adequately, new development located upstream of Brookside may increase the flood risk at Brookside.

Risk to Possible Development:

Development is not advised within 30-50 metres of Town Beck, especially on the land immediately upstream of the railway line as this culvert has a low capacity.

Additional Information

We had an informal discussion with the Head Teacher of North Elmham Primary School. He knew of no flooding incidents. We also spoke with the resident of 30 Cathedral Drive. She said that in autumn 2000 the beck had reached bankfull, but she knew of no property flooded in the village at this time.

Access for Inspection:

Access via North Elmham School, Cathedral Road and track from Old Hall.

B.7.2 Street Farm Drain

This drain runs from Street Farm from south to north along a field boundary before turning through a 90 degree right bend and flowing across the Town Beck floodplain behind Eastgate Street.

The drain is less than a metre wide and has a bank height of approximately a metre. The channel is 2 metres wide at bankfull. It is considered that the drain will pose limited flood risk as it is unlikely to exceed bankfull in the 1% event.

Existing Properties at Risk:

None.

Risk to Possible Development:

Development is not advised within 10 metres of this drain.

Access for Inspection:

Access via path from Eastgate Street to Oak Avenue.

B.8 Old Buckenham

This village was visited on 26 January 2005.

Old Buckenham is located in the headwaters of the River Thet. The village is located on a ridge, with the northern edges of the village draining to the north and west and the southern part of the village draining to the south. There are no significant watercourses within the settlement. The only potential sources of flood risk were some small drains on the southern outskirts of the village. They are shown in Figure C.M1.

The watercourse to the south of the village which forms one of the upper reaches of the River Thet was visited. The land rises steeply from this stream up to the village of Old Buckenham, therefore it was not considered to be a source of flood risk to the village.

Residents of Cake Street requested sandbags twice in January 2007. It is unsure whether it did actually flood, and what the source of flooding was.

B.8.1 Oaklands Drain

This drain flows along the edge of a field, behind houses on Oaklands and St Andrew's Close. It was dry and overgrown when inspected. The drain dropped steeply to the east. This drain is not considered to pose a significant flood risk.

Properties at Risk:

None.

Risk to Possible Development:

None.

Access for Inspection:

Access via Crown Road.

B.8.2 Crown Road Drains

These drains flow downhill from north to south down either side of Crown Road. A drain also enters the westerly drain on the right bank.

Channel:

All three drains are generally overgrown and have steep gradients. There was a very small amount of water in the westerly drain when inspected and no water in the easterly drain or the tributary of the westerly drain. The main drain was 0.3 metres wide at the base and 3 metres wide and 1.2 m deep at bankfull.

Floodplain;

The flood risk is limited from all three drains due to the small catchment area and steep gradient. However, the gradient reduces as the drains reach the cross roads with Ragmere Road, and it is assessed that water will spill onto the road at this point in the 1% event. This location is shown in Figure B.15.

Properties at Risk:

None.

Risk to Possible Development:

None.

Access for Inspection:

Access via Crown Road.

Figure B.15: Crown Road Drain, looking downstream and junction with Ragmore Road

B.8.3 Harlingwood Lane Drain

This drain flows from east to west along Harlingwood Road. It is located nearby Cake Street and might have been the source of concern and/or flooding in January 2007 when sandbags were requested.

Channel:

The ditch is 0.8 metres wide at the base and 2-3 metres wide and around 1.5 metres deep at bankfull.

Floodplain:

In the 1% event it is likely that water will remain within the banks and not spill onto the road or fields adjoining the drain.

Properties at Risk:

None.

Risk to Possible Development:

None.

Access for Inspection:

Access via Harlingwood Road.

B.9 Saham Toney

These watercourses were studied on the 1 March 2005

The village of Saham Toney has been identified by Breckland District Council as an area where it is possible future development may take place.

The sites around the village are presently occupied by agricultural land. Watton Brook flows to the south of the village. The flood extents for the Brook have been defined through constructing a hydraulic model. This is described in Appendix D. There are also a number of ordinary watercourses in the village which have been mapped using the Level A technique. The watercourses studied are shown in Figure C.N1.The watercourses impacting on the sites around Saham Toney are ordinary watercourses along the outskirts of the village. These watercourses eventually discharge into Watton Brook.

Anglian Water reported that there is a sewer flooding issue in Bell Lane. The flooding frequency is noted as 1:10 years.

B.9.1 Saham Toney Stream

This is an ordinary watercourse which flows from the B1077 around the edge of the whole village before the confluence with Watton Brook.

It was not possible to get access to the whole length of this drain, the total length of the studied section is approximately 700m.

Channel:

The studied section of the watercourse starts with a 100mm diameter culvert outfall. The channel begins as a small roadside drain following the path of Pages Lane. Along this section of the watercourse the right bank occasional drops to the level of the road to enable water to drain into the ditch. This effectively means that the height of the right bank is 80cm whereas the left bank is over 1.4m.

There are two culverts in the upstream section; both are 200mm in diameter, the second culvert was partially silted at the time of inspection.

The watercourse exits culvert at Thatched Cottages, where it deviates from the path of the road. The channel in this section is 1.3m deep with the left bank 100mm higher. There was no access to the watercourse downstream of this point until an arch bridge at Hills Road. The channel in this section is shallow with gently sloping banks.

The next access to the watercourse was at The Lodge, where the watercourse enters a small area of woodland. A sluice gate in this area forms a pond in the wooded area. In the 1% flood event the sluice gate would be bypassed with flood water covering all of the wooded area.

Upstream of a 1.5m arch bridge under Ploughboy Lane is a 500mm diameter outfall and the confluence with another drain. This drain follows the path of Ploughboy Lane and is wide with steep sided banks. Downstream of the arch bridge the watercourse becomes much larger being over 5m wide and 2m deep.

The downstream section close to the Bird Sanctuary was not studied as it is largely in the floodplain of Watton Brook.

Floodplain:

It is assessed that there is a risk of flooding from this watercourse along all of the studied section. This flooding would be greatest at the structures at Hills Road and Ploughboy Lane which would restrict flow.

It is assessed that Pages Lane would be liable to flooding at the upstream end of the studied reach and at Hills Road culvert.

Existing Properties at Risk:

None in the studied section; however there was no access to the watercourse at the back of properties off Pages Lane.

Risk to Possible Development:

The studied stretch of the watercourse is already largely developed, any additional development close to the watercourse would not only be at risk of flooding but the additional hardstanding would increase the risk of flooding to existing properties.

Access for Inspection:

Access via Pages Lane and Chequers Lane.

Figure B.16: Saham Toney Stream

B.9.2 Saham Toney Field Drains

To the west of Saham Toney there are a number of large field drains, flowing from Richmond Road and Saham Mere. These are all field drains, which eventually discharge into the Watton Brook. It was only possible to perform a detailed study for a 450m section of these drains due to access restrictions.

The studied drain flows from Richmond Road.

Channel:

At the upstream end of the studied watercourse, near Richmond Road, there are three outfalls, two are 200mm diameter and the other is 100mm in diameter. At the outfalls the right bank is 1.3m high while the left bank is over 2m high. The level of the banks does gradually become equal at 1.6m high.

Although it was not possible to perform a detailed study of the watercourse flowing from Saham Mere, it was possible to observe the size of the channel. The channel at the confluence with the drain flowing from Richmond Road is approximately 2m deep and 3m wide, both banks where lined by trees.

Floodplain:

The size and slope of the catchment along with the capacity of the channel means that there would be only a limited amount of flooding in the upstream section. At the confluence of the two drains the catchment becomes relatively flat and the extent of any flooding would be greater.

Existing Properties at Risk:

None.

Risk to Possible Development:

It is assessed that at present the area close to these watercourse is at risk of flooding in the 1% flood event. The amount of land at risk would increase the further downstream. In the studied section the area assessed to be at the greater flood risk is at the confluence of the two drains.

Access for Inspection:

Access via Church Farm.

B.10 Shipdham

Shipdham was visited on 24 November 2004.

The sites around the village are presently occupied by agricultural land. The village of Shipdham lies at the top of the catchments for the River Blackwater (Upper Yare) and Wissey River. Most of the village drainage works on soakaway systems.

The watercourses impacting on the sites around Shipdham are the Main River Blackwater and ordinary watercourses. These are shown, along with the 1% flood outline in Figure C.O1.

The Blackwater River flows to the south of Shipdham. At this point the river is about a metre wide and is unlikely to provide a significant flood risk as the land rises steeply away from the stream.

The River Upper Yare has been modelled for the River Yare Flood Risk Study (BBR, 2005). The model includes the upper reach of the river which is called River Blackwater. The use of this model is documented in Appendix D.

Surface water at the site drains naturally in three directions, away from a ridge in the middle of the village.

- To the east and south, the site drains directly into River Blackwater
- To the west, the sites drain into sink holes via a series of drains.
- To the north, the site drains via a series of drains into the River Wissey, which becomes Main River downstream of Bradenham.

Anglian Water reported that sewer flooding occurs in Chapel Street with a frequency of twice every 10 years.

Breckland District Council reported that sandbags have been requested several times in 2006 and 2007 in Market Street, at the north-east corner of the village.

B.10.1 Watery Lane Drain

This drain is an ordinary watercourse which runs along field boundaries and Watery Lane. The length of the studied section is approximately 280m. The watercourse ultimately drains into the Blackwater River below Shipdham.

Channel:

The watercourse is a drainage ditch, which runs along the border of the arable fields and Watery Lane.

It is connected by a 300 mm diameter culvert to a large pond upstream of the study reach which attenuates significant run-off from the north.

The upstream extent of the studied area is densely vegetated and access to the channel in some locations was restricted. The channel is overgrown but has approximately the same dimensions throughout the studied area. The channel is 1.4m deep and 2m wide. There are two ponds on the watercourse; one is at the upstream limit of the studied area and the other is at the end of the field.

Along Watery Lane the left bank becomes slightly higher than the right bank. Also in this area there are two structures. Both are 600mm diameter pipe culverts, the first, under a farm access bridge is partially silted.

Housing on the right is slightly raised; however these areas are still not as high as the left bank. There is one property (Fair View) which is assessed to be at risk of flooding in a 1% flood event. This property is slightly lower than the others and is across the road from the partially silted culvert.

Floodplain:

The catchment for the watercourse comprises gentle sloping arable fields. Although the catchment is relatively small there is a lot of water held in the two ponds. As these are part of the watercourse and have smaller banks than the main channel they will not attenuate flow.

The area assessed to be at risk of flooding in a 1% flood event would be either side of the watercourse upstream of Watery Lane, and on the right bank at Watery Lane. The restricted capacity of the first culvert would increase the risk of water going out-of-bank.

Existing Properties at Risk:

Fair View, Watery Lane.

It should also be noted that any development within the catchment to the north of the large pond is likely to increase flood risk to properties next to Pound Green Lane.

Risk to Possible Development:

It is assessed that development on Watery Lane or close to the watercourse would be at risk of flooding from the drain. In addition an increase in stormwater runoff as a result of increased impermeable areas would increase flood risk to existing properties at Watery Lane.

Access for Inspection:

Access via Watery Lane.

Additional Information

Breckland Council has previously looked at increasing the capacity of this watercourse.

Figure B.17: Watery Lane Drain looking Downstream

B.10.2 Parkland Stream

This stream is an ordinary watercourse which runs from the centre of Shipdham along field boundaries into the River Blackwater.

The length of the studied section is approximately 360m.

Channel:

Upstream of the studied section the watercourse is a natural stream, while the path of the watercourse has been altered in the studied section, to follow field boundaries.

The upstream extent of the studied area is within a wooded area at the back of properties on Parkland Avenue (Figure B.15). The channel in this location is a natural wide stream with steep banks. There is an 800mm diameter pipe culvert in this section, which at some stage had a trash-screen, but this is now lying in the channel.

Away from the forested area the channel path has been adjusted away from the natural valley to follow field boundaries. The channel in this area is slightly narrower and deeper than the upstream section. The right bank is lower due to the fields sloping to the south west, toward the River Blackwater.

Where the main channel diverts off to the right, there is an inflow from a smaller drain flowing towards the village of Shipdham. There is another 90 degree bend at the bottom of the valley, where the stream course veers left and returns to the natural valley.

The watercourse joins the River Blackwater just downstream of a farm access bridge at Hall Farm.

Floodplain:

The watercourse catchment is gentle sloping arable fields and residential land.

The capacity of the channel especially in the upstream section of the study area is large, therefore the extent of any flooding would be limited. It is assessed that the main risk of flooding from this stream would be caused by blockages in the channel from vegetation, especially at the culvert.

Existing Properties at Risk:

None.

Risk to Possible Development:

It is assessed that this stream will have only a limited impact on the possible development area. Development on the right bank of the watercourse would be at risk of flooding given the natural slope of the land. Any development between this watercourse and the River Blackwater is also assessed to be at risk of flooding.

As at the date of this report, there was some development occurring on the land next to the "natural stream" upstream of the study reach. The risk created by this on-going development should be considered in a detailed assessment.

Access for Inspection:

Access via Parklands Avenue.

Figure B.18: Parkland Stream behind Parkland Avenue, looking upstream

B.11 Swanton Morley

Swanton Morley was visited on 12 January 2005.

Swanton Morley is located on an escarpment above the River Wensum valley. The village drains from west to east via two small steep valleys down to the River Wensum. The flood risk of these two small streams has been assessed. They have a combined length of 650 metres. They are shown in Figure C.P1.

B.11.1 Church Stream

This stream rises near the junction of Town Street and Gooseberry Hill and flows downhill in a steep sided valley. Below the church the stream valley widens and water will spill onto a floodplain approximately 50 metres wide. The flood risk assessment was undertaken by viewing the stream from the church. No detailed inspection of the channel was made. However, the topography of the area meant that the 1% flood outline could be determined through viewing from an elevated position.

Properties at Risk:

None

Access for Inspection:

Limited, viewed from the church.

B.11.2 Woodgate Stream

This stream rises in the hamlet of Woodgate and flows through pasture from east to west. It flows into Penny Spot Beck, a tributary of the River Wensum.

Channel:

The channel within the study area is overgrown and less than a metre wide.

Floodplain:

The stream will have a limited flood envelope. Flooding will be more extensive on the left bank due to the lower ground.

Properties at Risk:

None

Access for Inspection:

Via track near Woodgate farm.

B.12 Weeting

Weeting was visited on 24 November 2004.

Weeting is more than 1 km from Little Ouse River and is well outside of the extreme flood outline. It is therefore considered not to be at risk from flooding from the Main River.

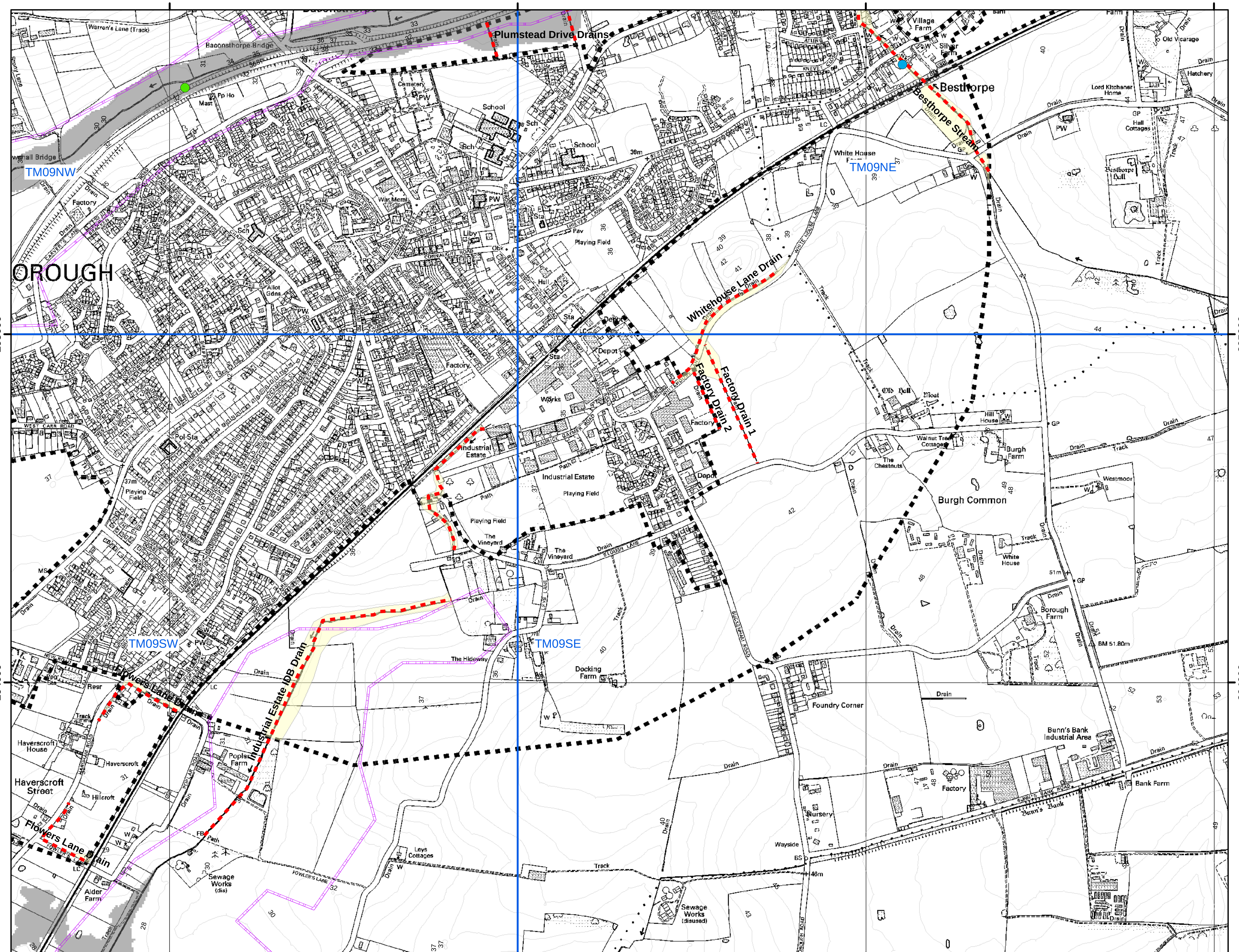
An ordinary watercourse passes to the east of Weeting and drains a catchment with an area of $13km^2$. A site visit showed that the fields upstream of Brandon Road had surface water ponding on the surface and were waterlogged. The stream runs adjacent to these fields and then passes through a culvert under Brandon Road. This culvert is susceptible to blockage, especially given the poor condition of the stream. However, blockage will mean that water collects upstream of the bridge as it unlikely to spill over the road, which is at a higher elevation. This means that the properties downstream of this culvert are at a lower flood risk, although a new residential development in this area appears to be at a lower elevation than the existing properties. Further downstream, the stream passes through a larger culvert on Rectory Lane and then across open fields with a no clearly defined floodplain.

This watercourse, passing to the east of the village is shown on the EA Flood Zone Maps. During the field visit the 1% flood extent was assessed to correspond well with the outline given in the flood zone maps. Given this observation, it was considered unnecessary to carry out further detailed study in this area.

Road flooding was reported on 17 July 2003 in Weeting by the Lynn News, but does not seem to have been particularly significant.

Appendix C: Flood Mapping of Possible Development Sites and Larger Villages

Flood maps have been produced for every proposed development site. They show the predicted fluvial flood extents for the 1 in 100 year return period, as well as the approximate location of historical flood records from all sources considered including fluvial, surface water, sewer, and infrastructure failure.



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Attleborough Site 1

Figure C: A1

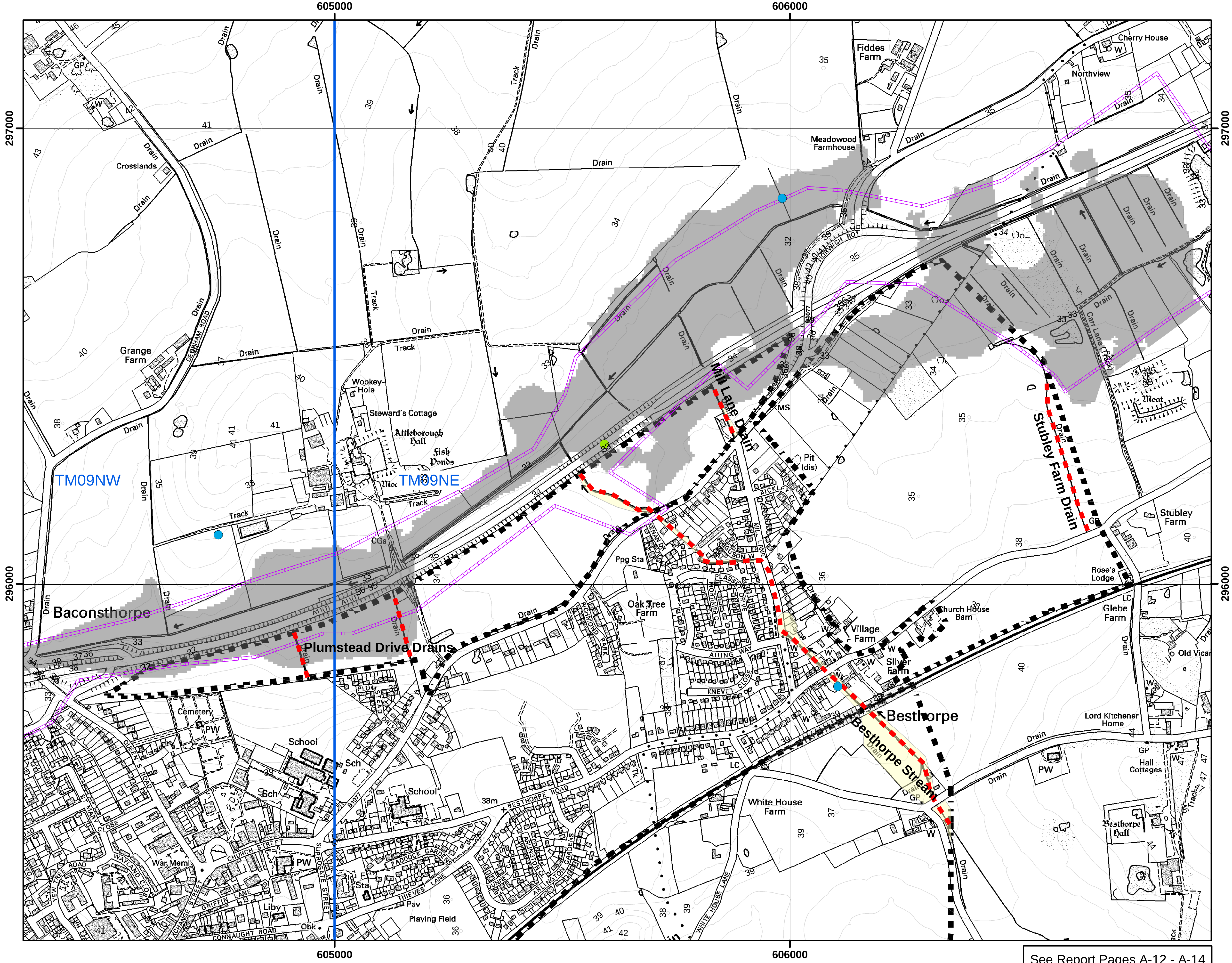
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-2 - A-11

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-A1.pdf



See Report Pages A-12 - A-14

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-A2.pdf

Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

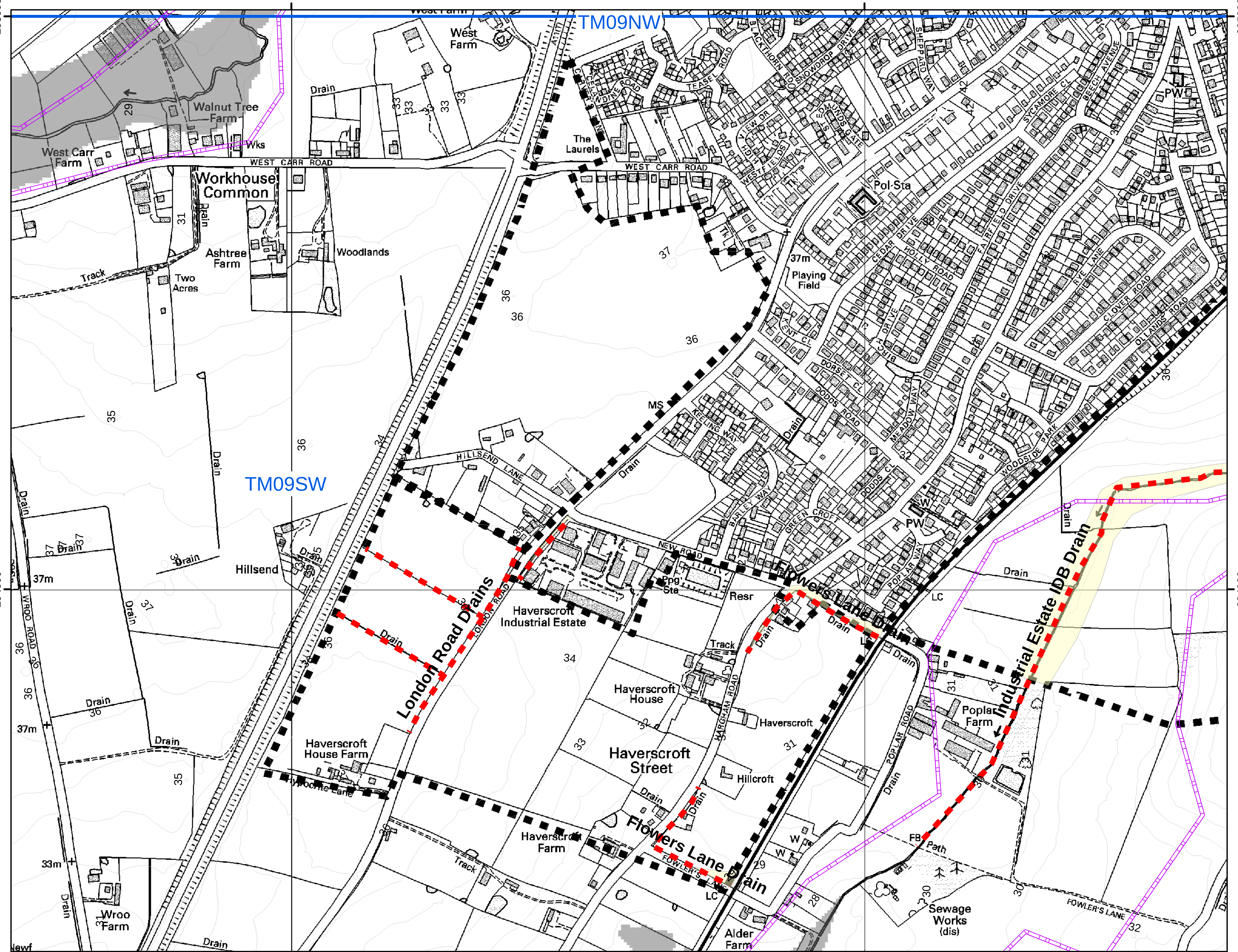
Attleborough Site 2 & 3

Figure C: A2

Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4



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Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Attleborough Site 4 & 5

Figure C: A3

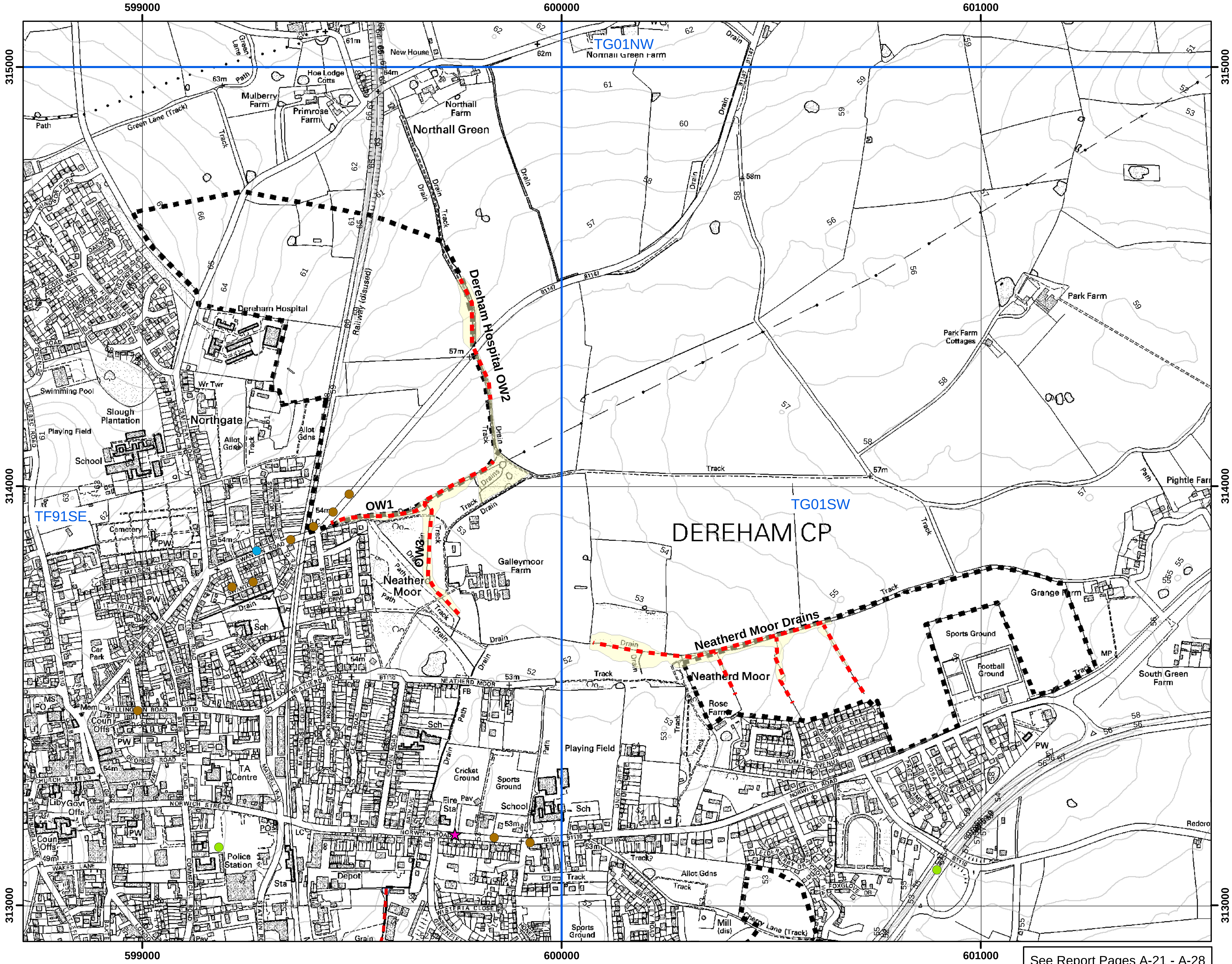
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-15 - A-19

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-A3.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Dereham Site 1 & 3

Figure C: B1

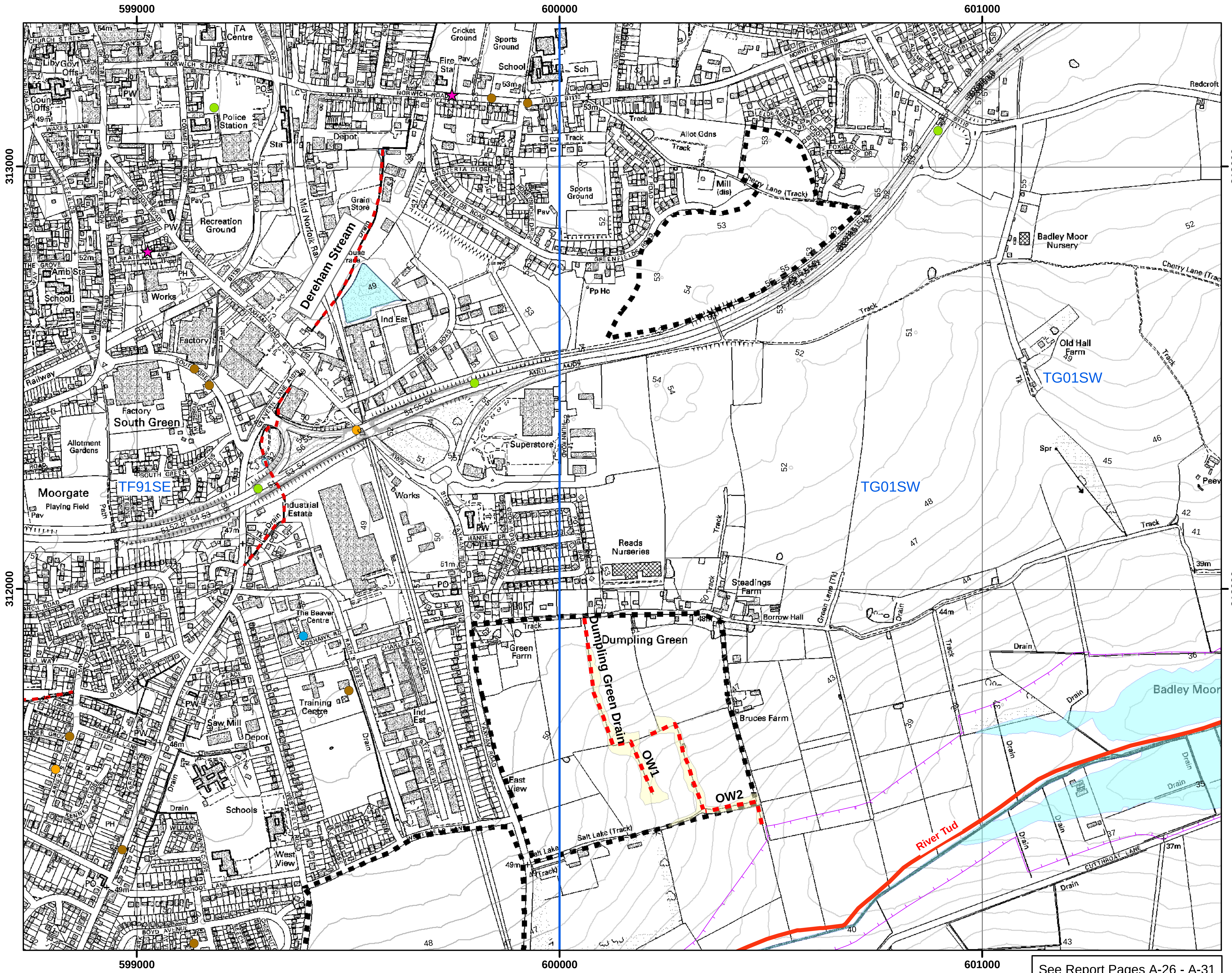
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-21 - A-28

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-B1.pdf



Legend

Modelled Fluvial Flood Extents:

1 in 100 year Envelope (Envelope derived from latest available modelling data)

1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)

1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

Fluvial Flood Events

Surface Water Flood Events

Infrastructure Failure Flood Events

Sewer Flood Events

Sandbag Deliveries

Flood Warnings

Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

Main River

Ordinary Watercourse

IDB District

Contours

1:10000 OS Tile extent

Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Dereham Site 2 & 4

Figure C: B2

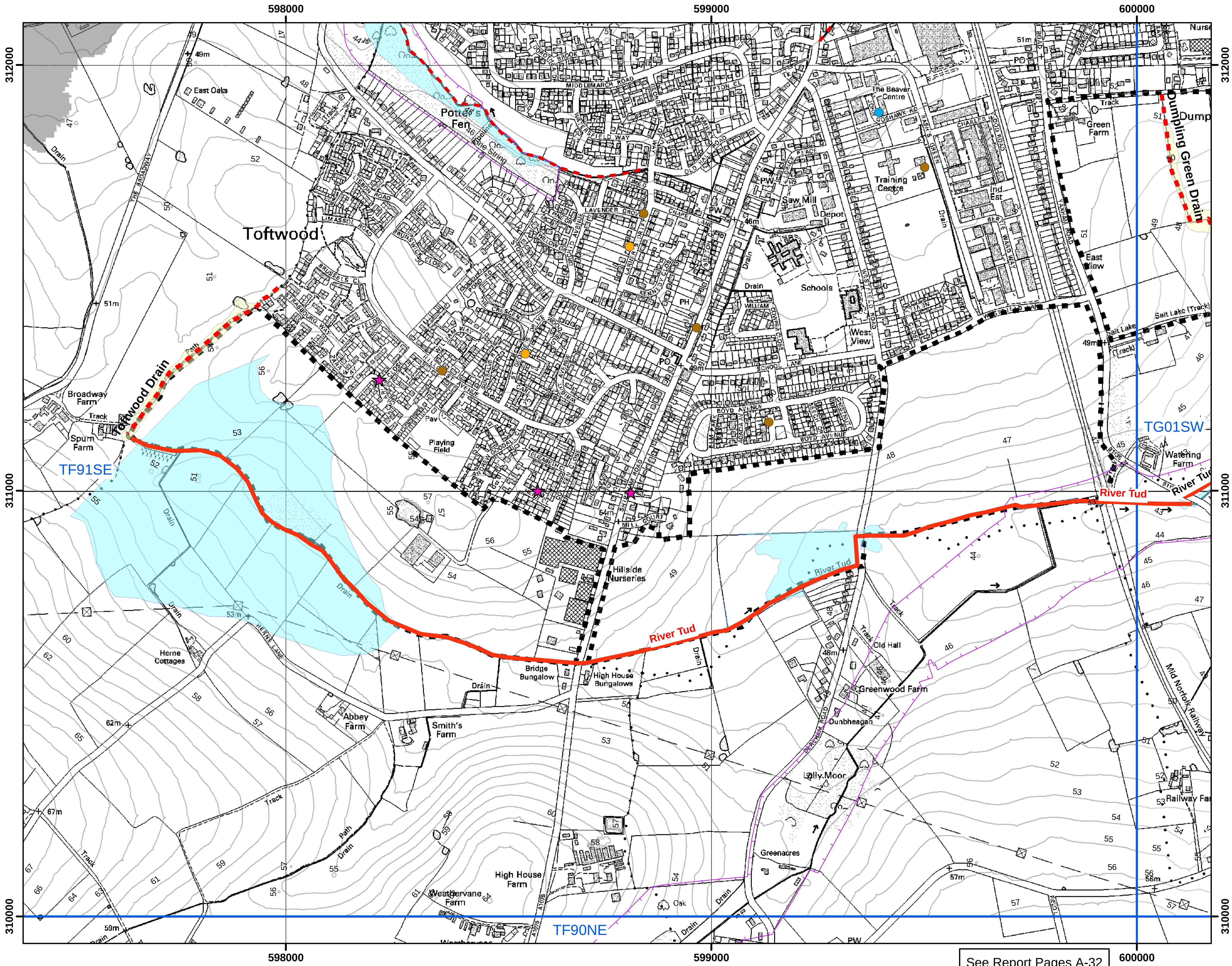
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-26 - A-31

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-B2.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Dereham Site 5

Figure C: B3

Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-32

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-B3.pdf

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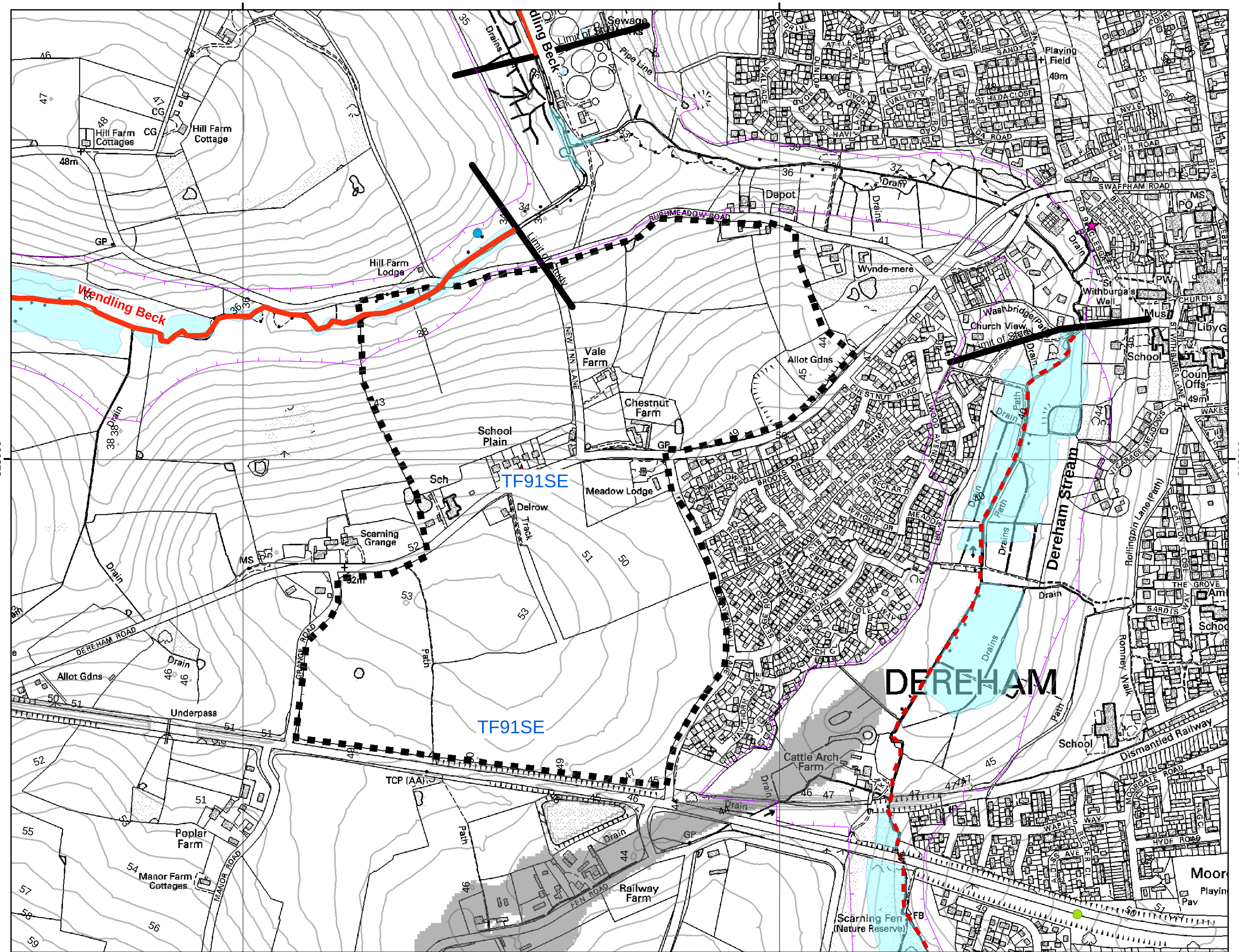


See Report Pages A-33

Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Dereham Site 6

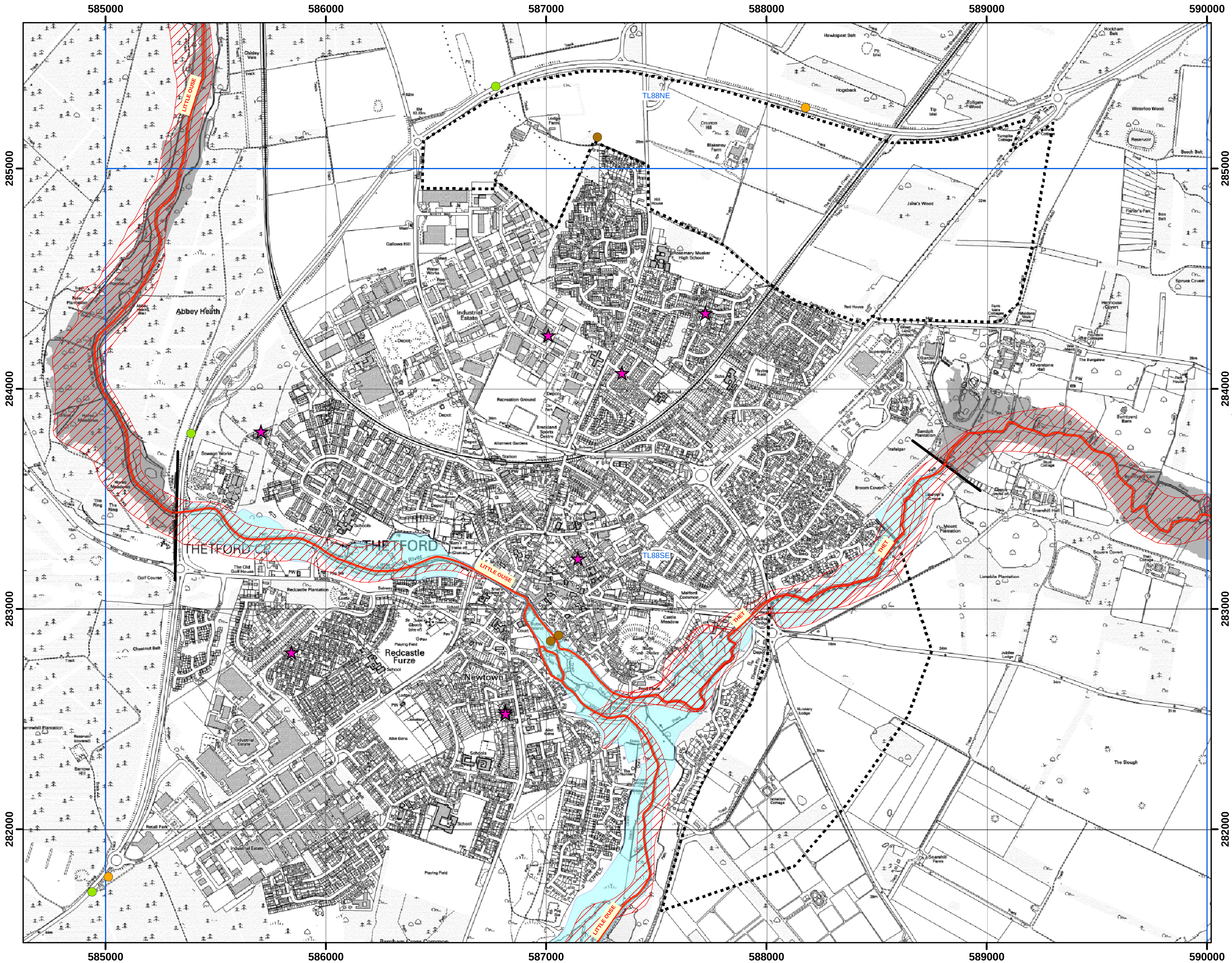
Figure C: B4

Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-B4.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Thetford

Figure C: D1

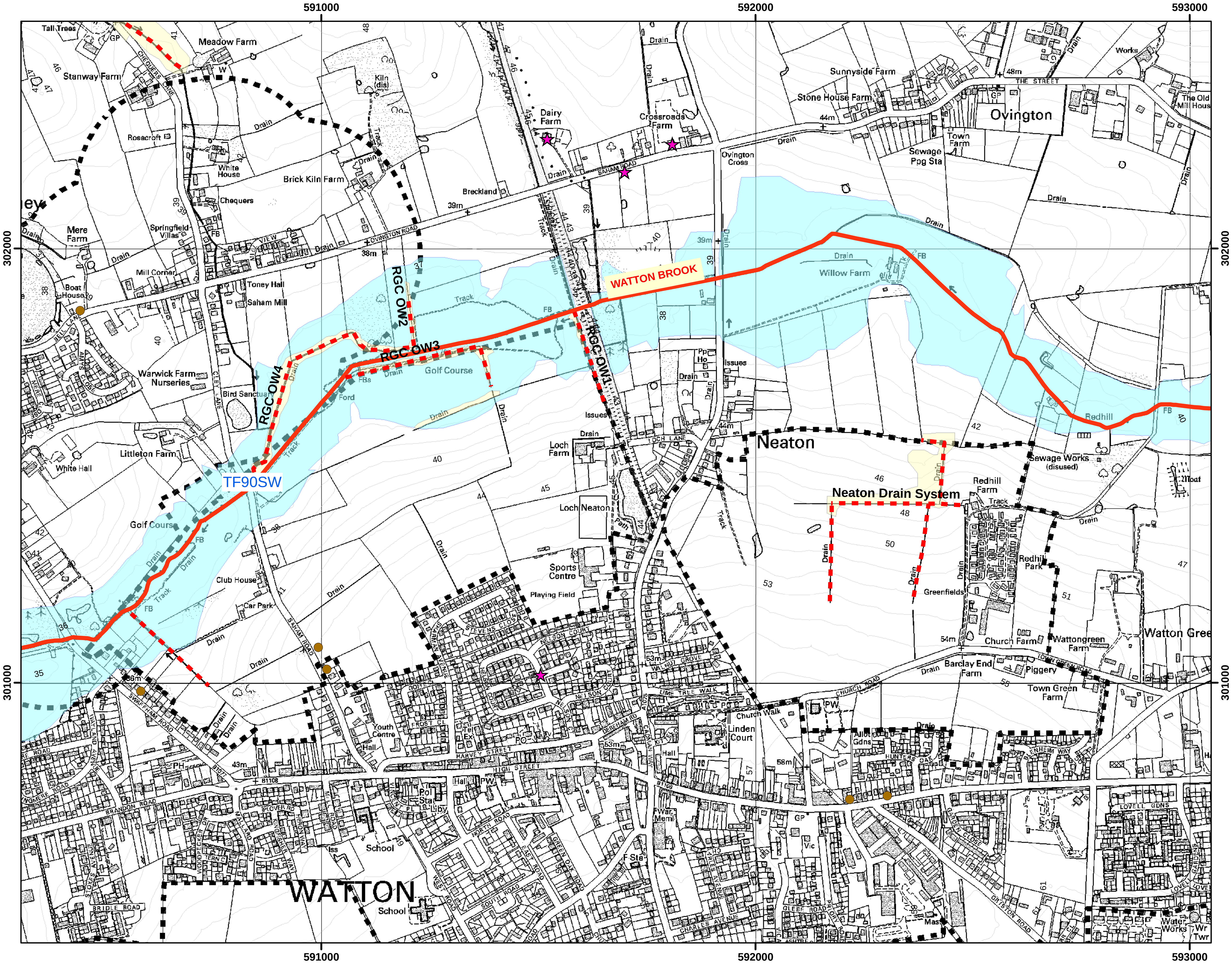
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-37 - A42

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-D1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Watton Site 1 & 2

Figure C: E1

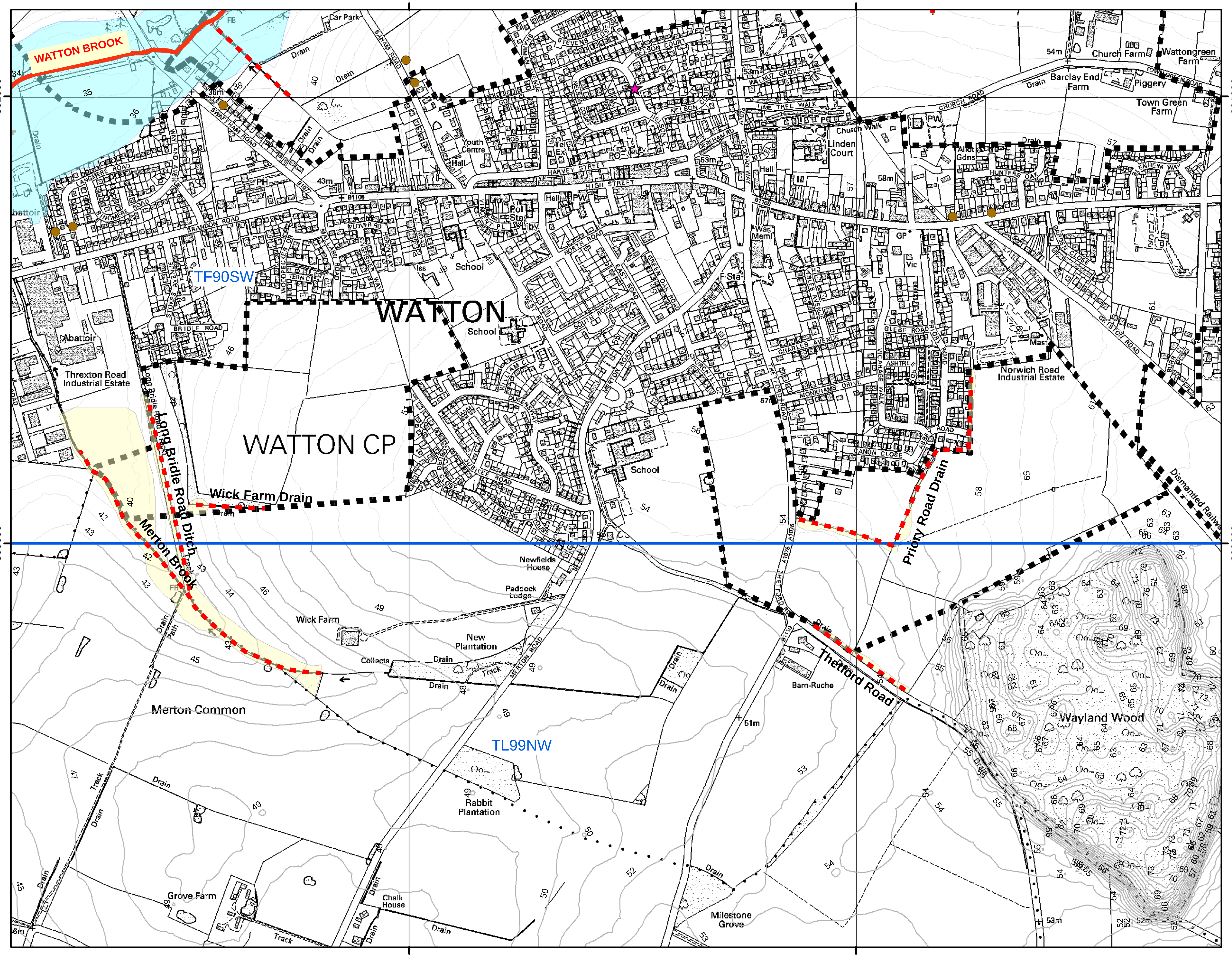
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-43 - A-52

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-E1.pdf



Legend

Modelled Fluvial Flood Extents:

1 in 100 year Envelope
(Envelope derived from latest available modelling data)

1 in 100 year Envelope
(Envelope derived from EA Flood Zone Maps)

1 in 100 year Envelope
(Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

Fluvial Flood Events

Surface Water Flood Events

Infrastructure Failure Flood Events

Sewer Flood Events

Sandbag Deliveries

Flood Warnings

Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993
(Source: Environment Agency)

Main River

Ordinary Watercourse

IDB District

Contours

1:10000 OS Tile extent

Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Watton Site 3 & 5

Figure C: E2

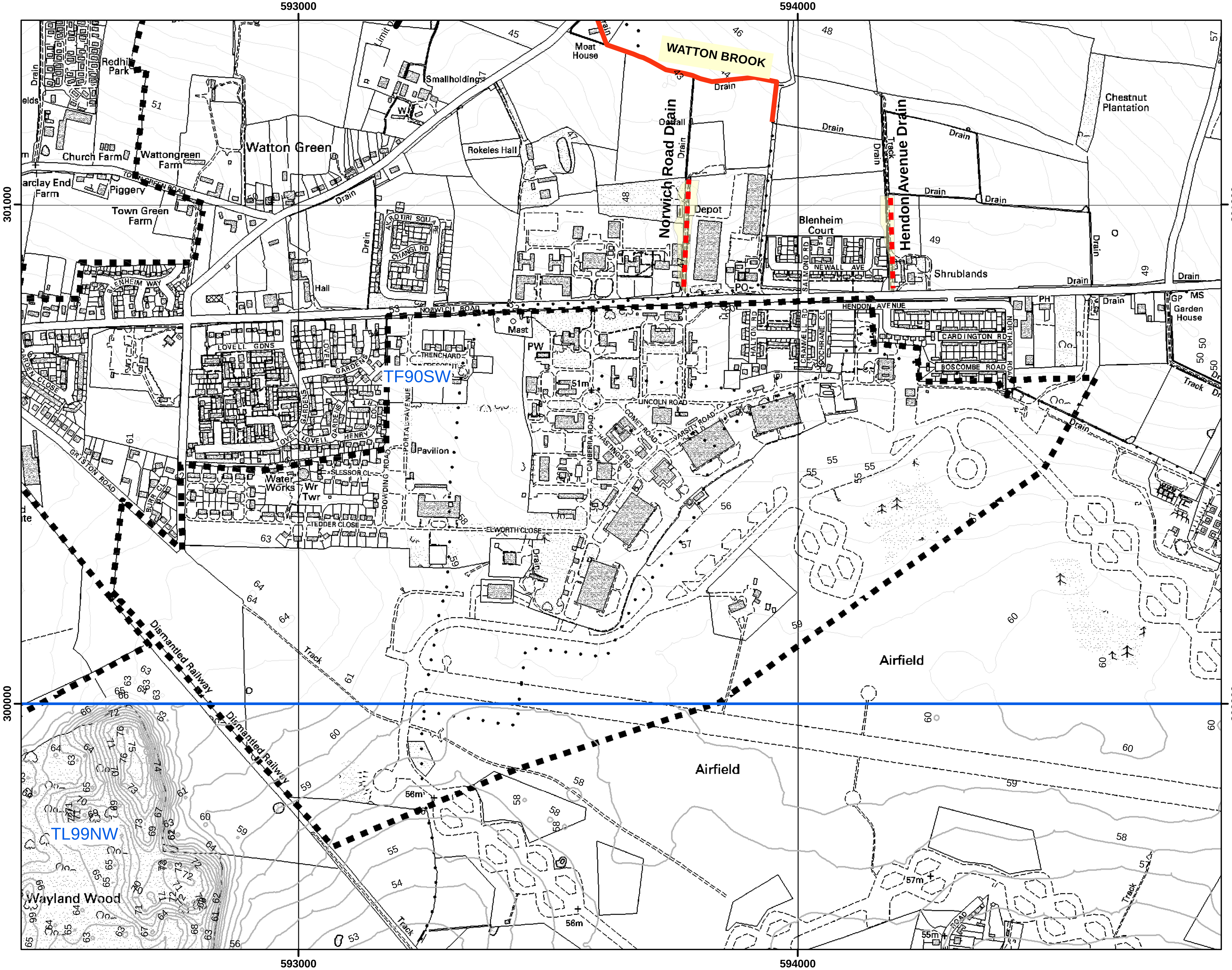
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages A-53 - A-58

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-E2.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Watton Site 4

Figure C: E3

Breckland

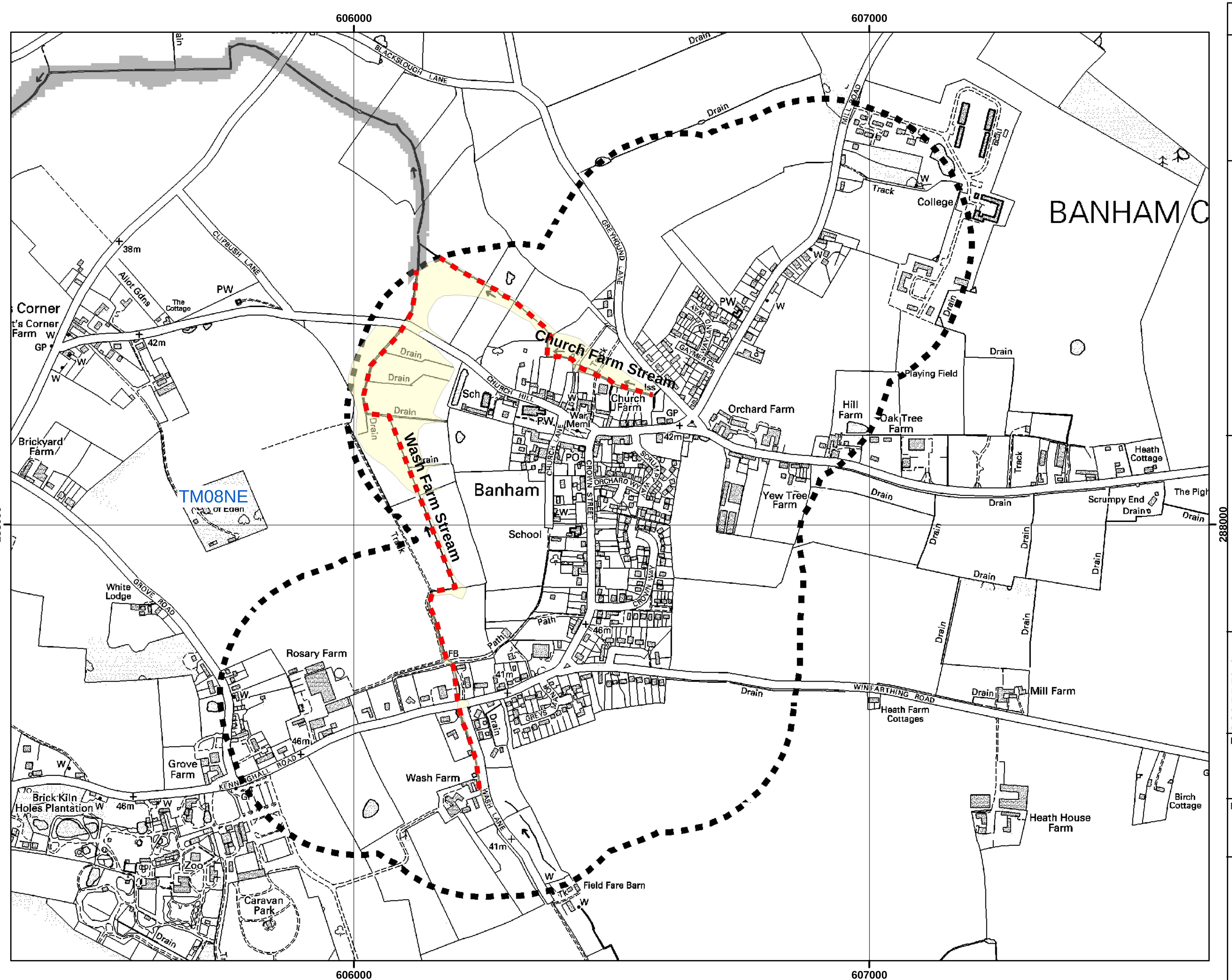
Mott MacDonald

Drawing Date 04/02/2008

Rev 4

See Report Pages A-55 - A-56

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-E3.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Banham

Figure C: F1

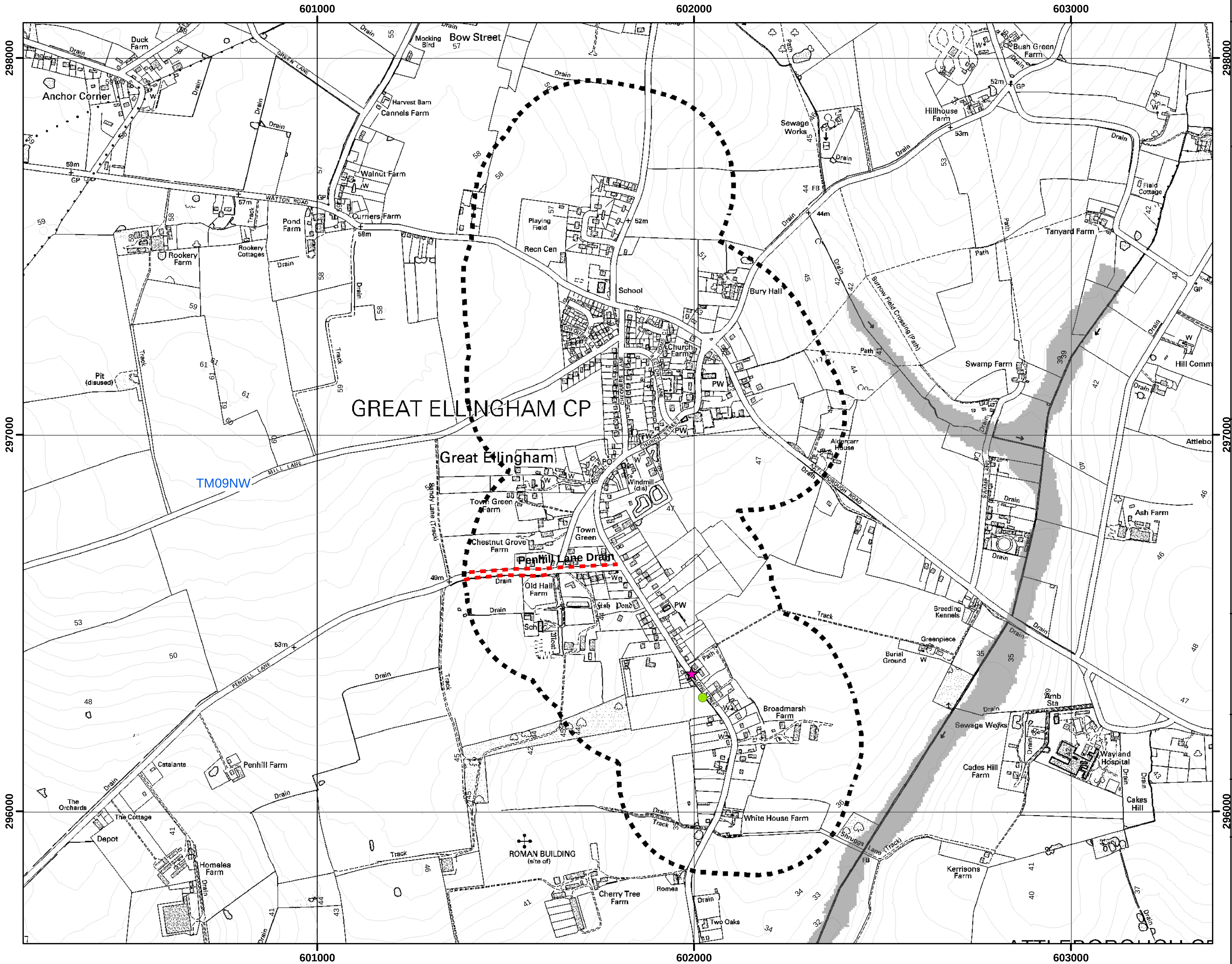
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-3 - B-6

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-F1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Great Ellingham

Figure C: G1

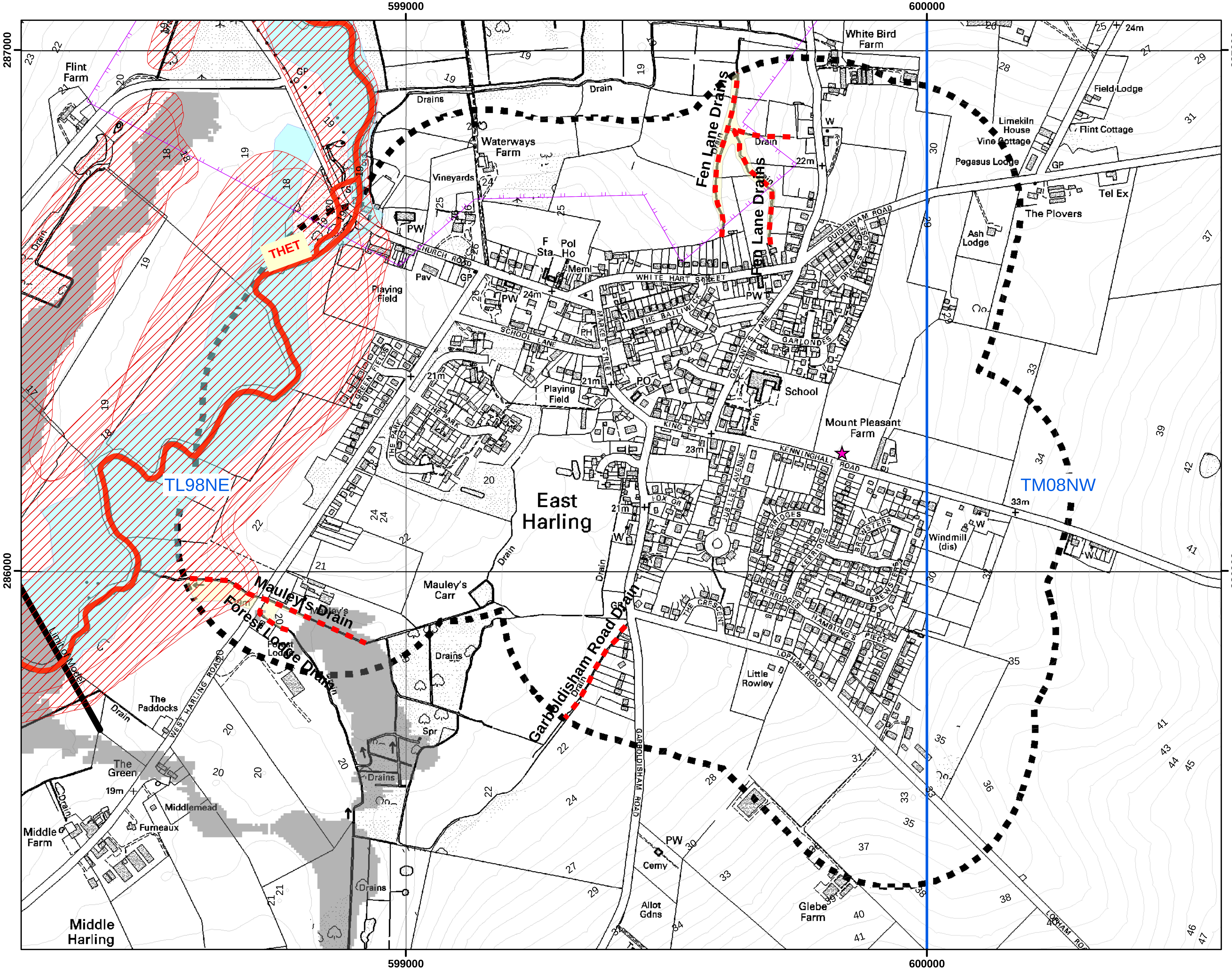
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-7 - B-8

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-G1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

East Harling

Figure C: H1

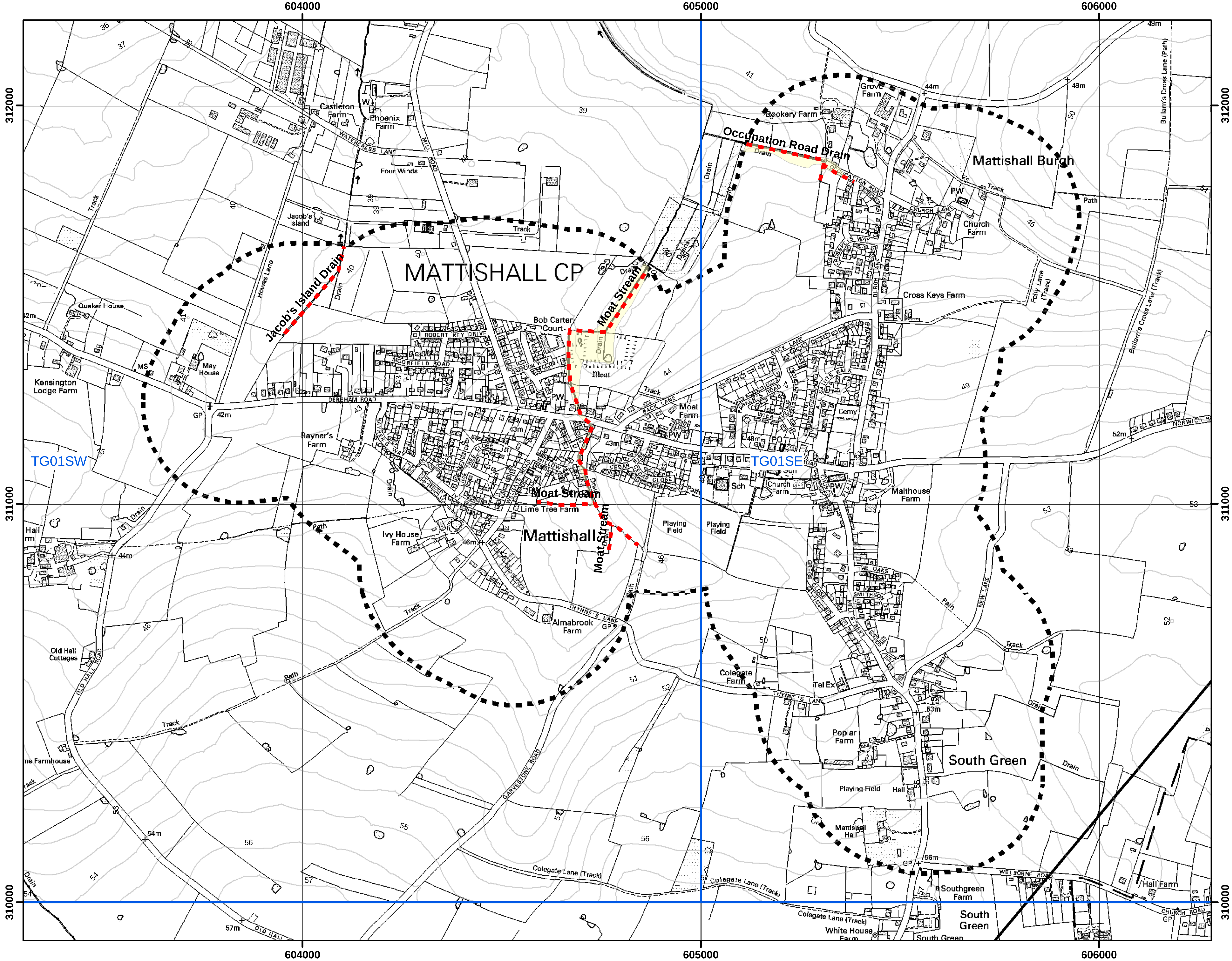
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-9 - B-11

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-H1.pdf



Legend

Modelled Fluvial Flood Extents:

1 in 100 year Envelope
(Envelope derived from latest available modelling data)

1 in 100 year Envelope
(Envelope derived from EA Flood Zone Maps)

1 in 100 year Envelope
(Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

Fluvial Flood Events

Surface Water Flood Events

Infrastructure Failure Flood Events

Sewer Flood Events

Sandbag Deliveries

Flood Warnings

Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993
(Source: Environment Agency)

Main River

Ordinary Watercourse

IDB District

Contours

1:10000 OS Tile extent

Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Mattishall

Figure C: I1

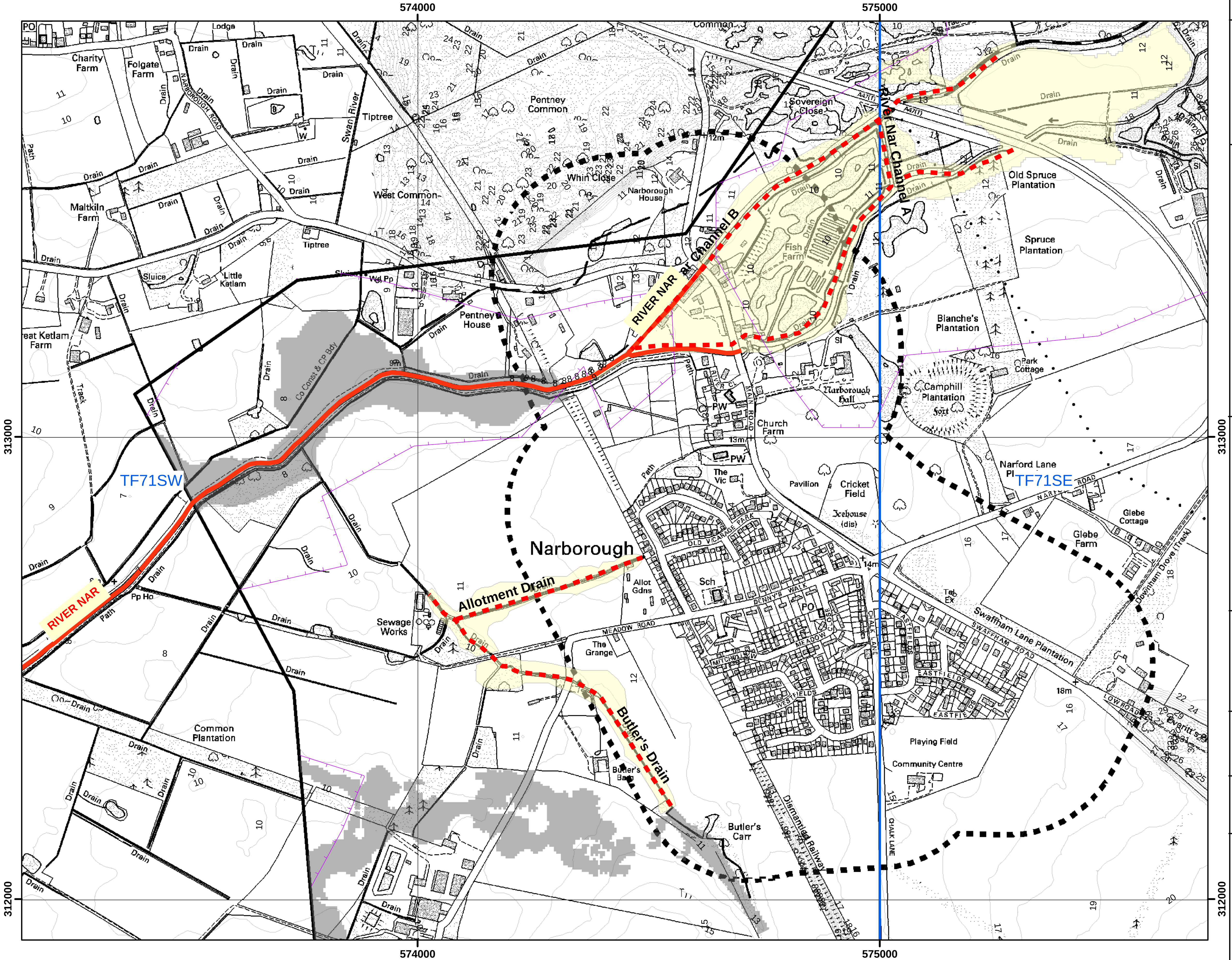
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-13 - B-16

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-I1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Narborough

Figure C: J1

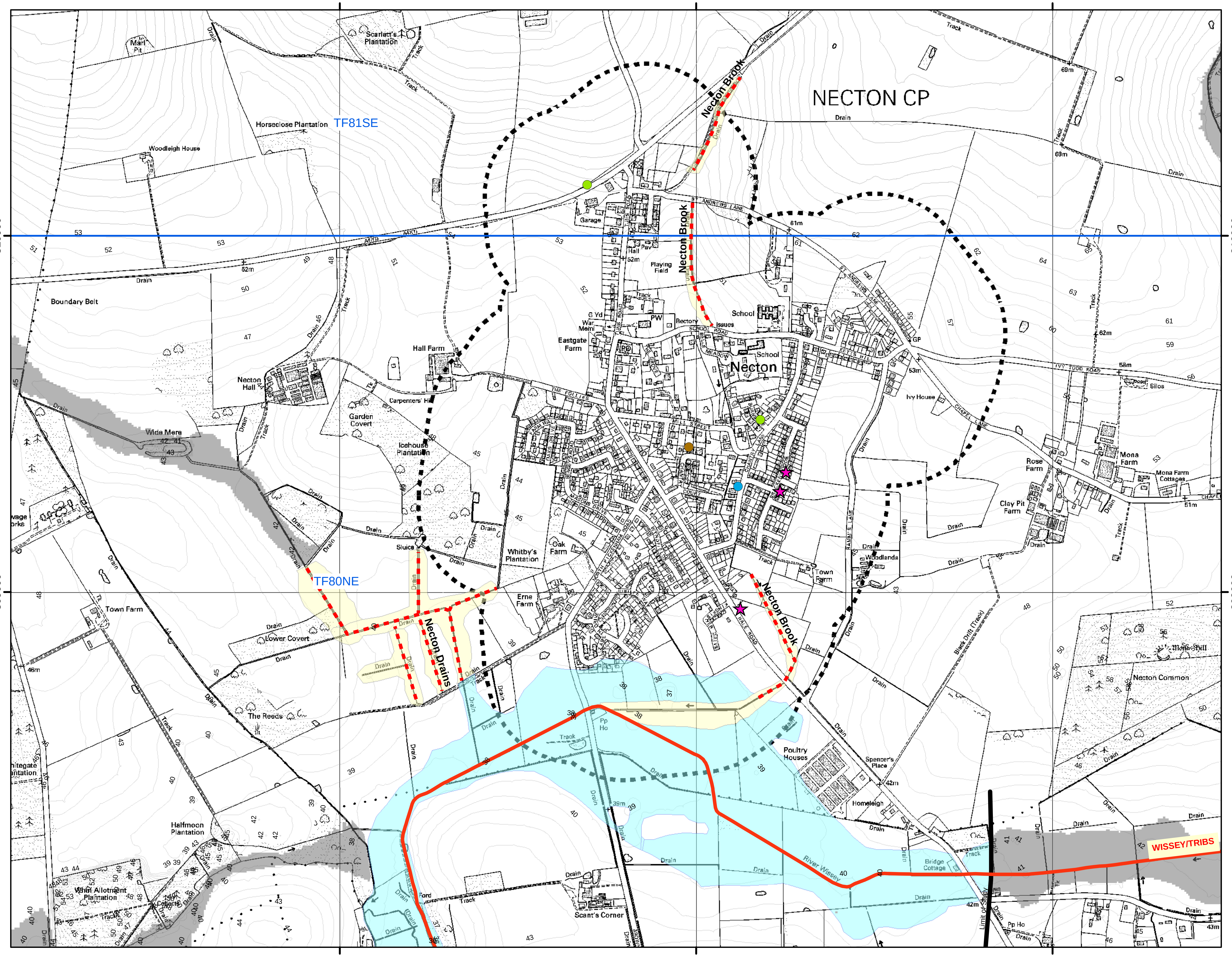
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-13 - B-16

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-J1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Necton

Figure C: K1

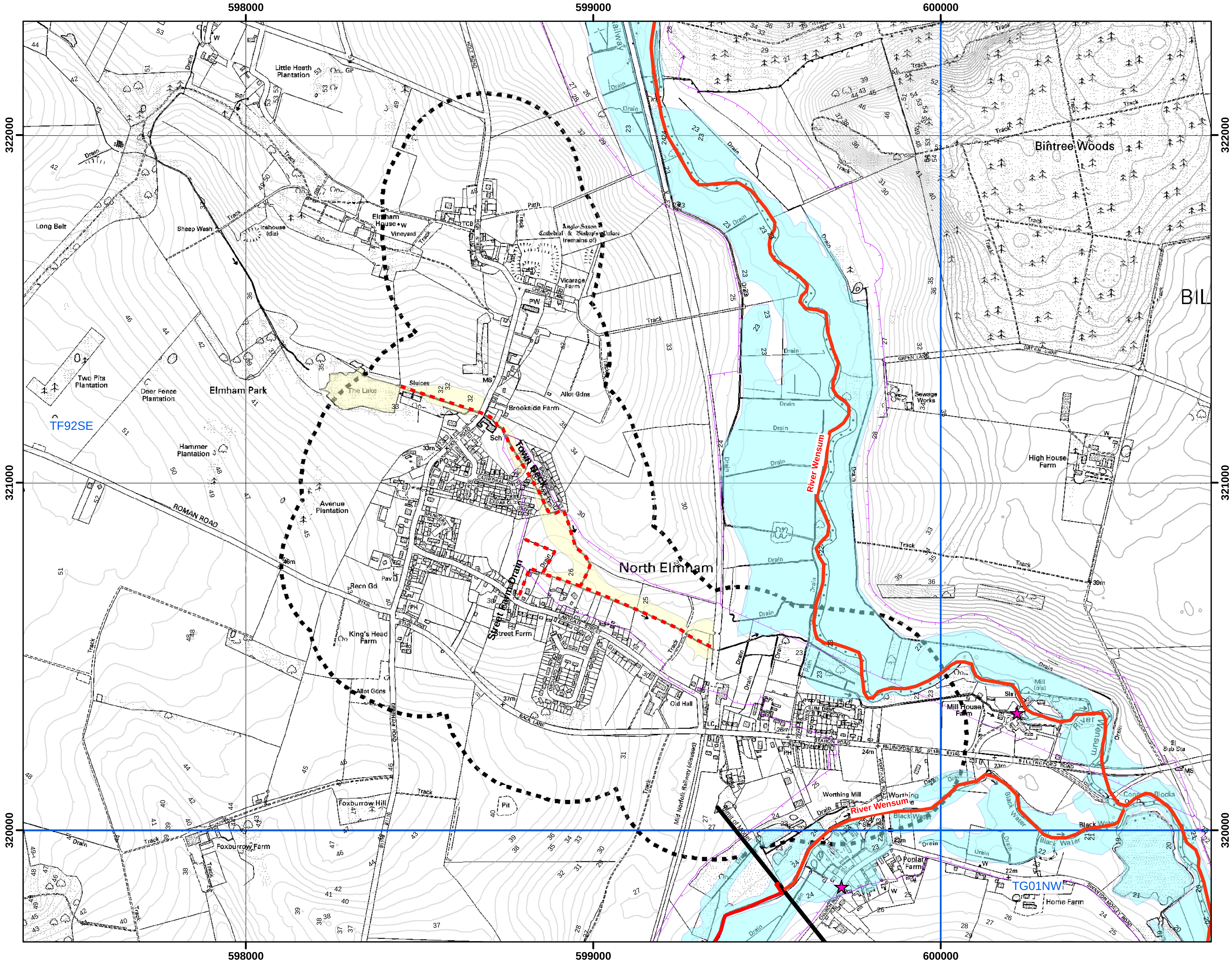
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-25 - B-28

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-K1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

North Elmham

Figure C: L1

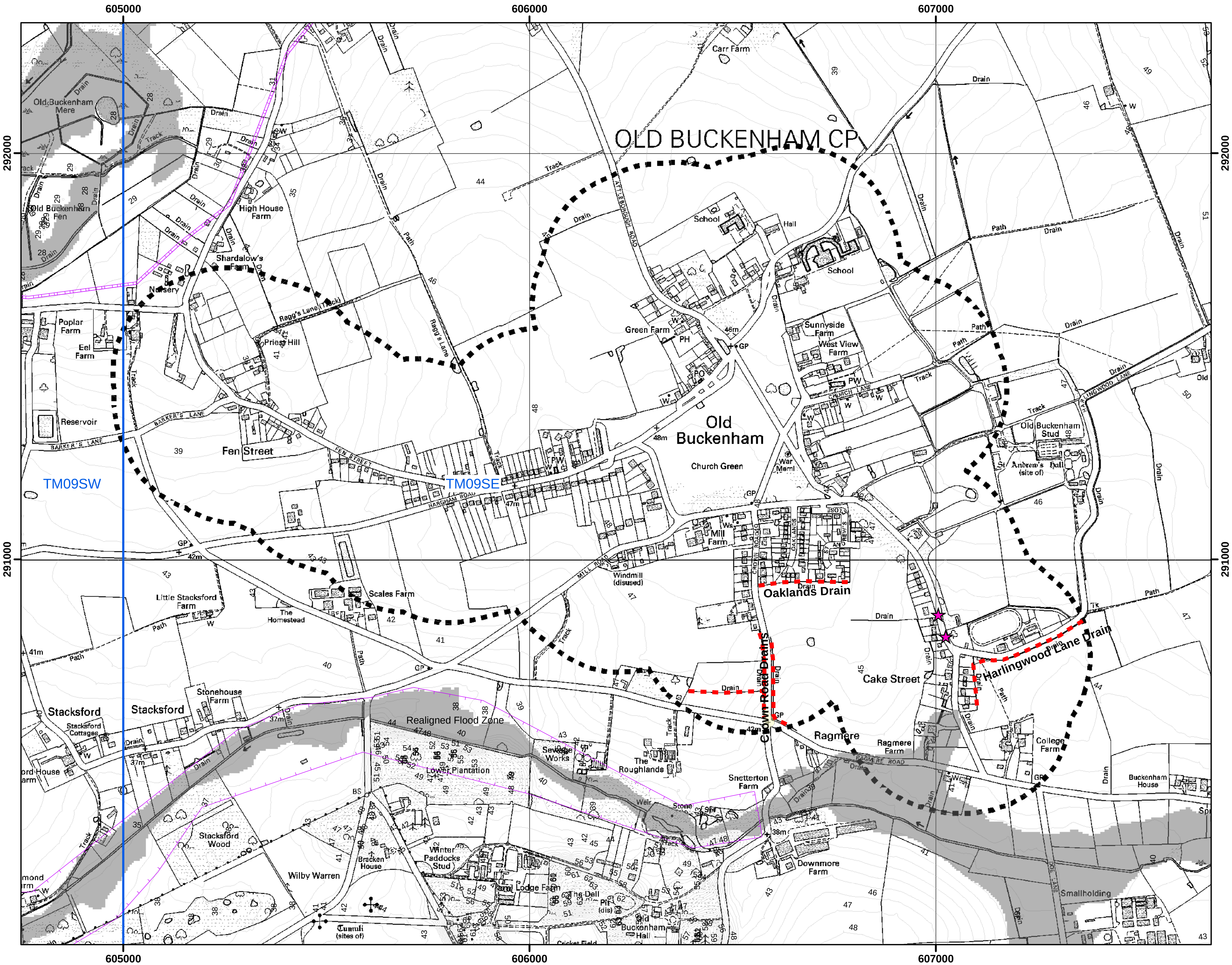
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-29 - B-32

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-L1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Old Buckenham

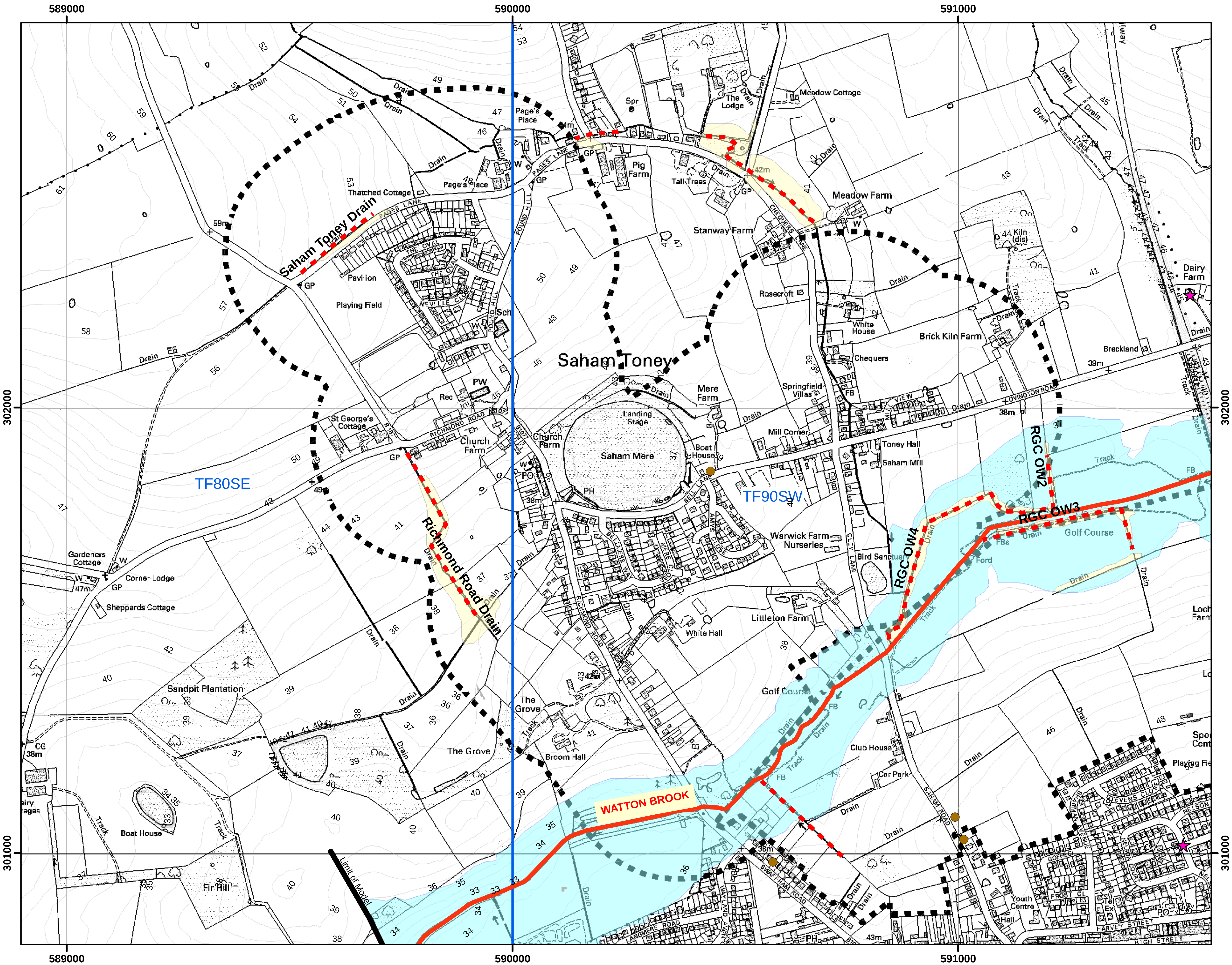
Figure C: M1

Breckland
Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-33 - B-35

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-M1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Saham Toney

Figure C: N1

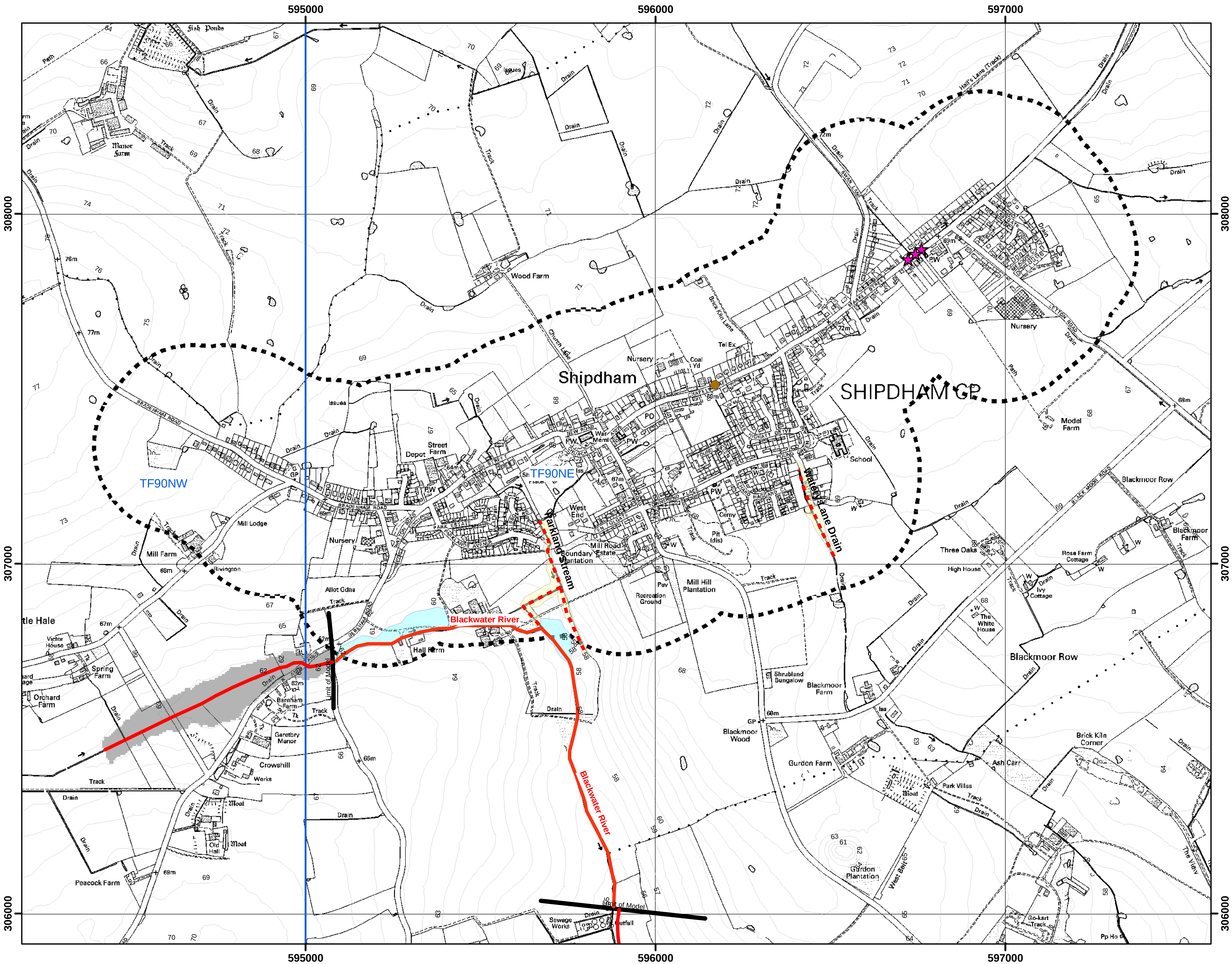
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-37 - B-39

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-N1.pdf



Legend

Modelled Fluvial Flood Extents:

- 1 in 100 year Envelope (Envelope derived from latest available modelling data)
- 1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)
- 1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

- Fluvial Flood Events
- Surface Water Flood Events
- Infrastructure Failure Flood Events
- Sewer Flood Events
- Sandbag Deliveries
- Flood Warnings
- Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

- Main River
- Ordinary Watercourse
- IDB District
- Contours
- 1:10000 OS Tile extent
- Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Shipdham

Figure C: O1

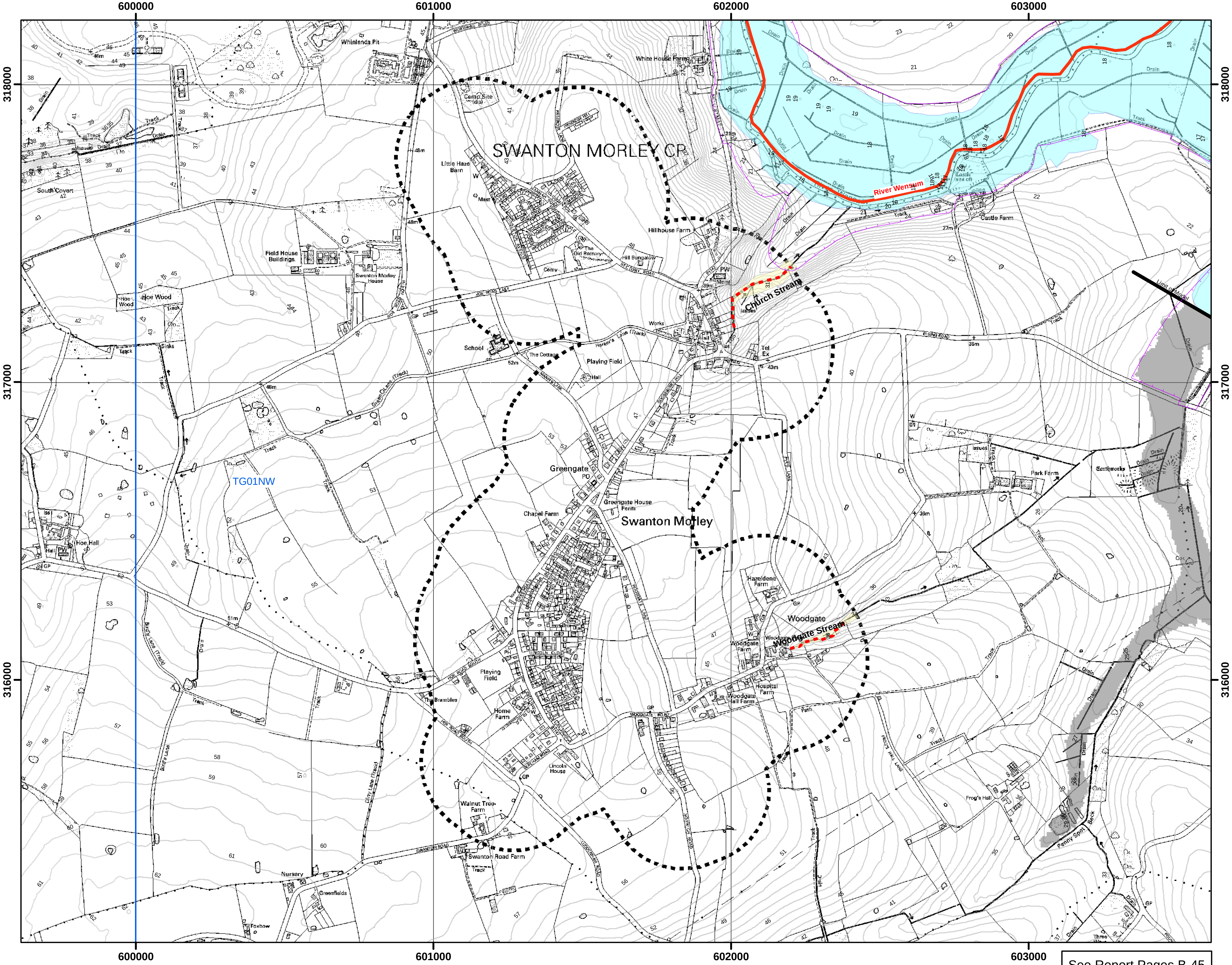
Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-40 - B-44

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-O1.pdf



Legend

Modelled Fluvial Flood Extents:

1 in 100 year Envelope (Envelope derived from latest available modelling data)

1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)

1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

Fluvial Flood Events

Surface Water Flood Events

Infrastructure Failure Flood Events

Sewer Flood Events

Sandbag Deliveries

Flood Warnings

Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

Main River

Ordinary Watercourse

IDB District

Contours

1:10000 OS Tile extent

Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Swanton Morley

Figure C: P1

Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-45

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-P1.pdf

Legend

Modelled Fluvial Flood Extents:

1 in 100 year Envelope (Envelope derived from latest available modelling data)

1 in 100 year Envelope (Envelope derived from EA Flood Zone Maps)

1 in 100 year Envelope (Envelope derived from engineering judgment also refer to flood zone maps.)

Historic Flood Events:

Fluvial Flood Events

Surface Water Flood Events

Infrastructure Failure Flood Events

Sewer Flood Events

Sandbag Deliveries

Flood Warnings

Maximum Historical Fluvial Flooding Extent based on records from 1937 to 1993 (Source: Environment Agency)

Main River

Ordinary Watercourse

IDB District

Contours

1:10000 OS Tile extent

Potential Development Area boundary

User Note

The locations of historic flood events are approximate and indicative only. It should be noted that certain locations not shown to be at risk from fluvial flooding may still be at risk from other watercourses not modelled in this study. Amendments will be required in future to account for information gathered subsequently e.g. changes in the hydrological response of the river or additional data arising from observed flood events.

Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Weeting

Figure C: Q1

Breckland

Mott MacDonald

Drawing Date 04/02/2008 Rev 4

See Report Pages B-47

Drawing ID:\238050 Breckland SFRA Update\Report\Updated Figures\Appendix C\Final_FigureC-Q1.pdf

Appendix D: Hydraulic Modelling

In Stage 2 of the study (2005), six new hydraulic models had been constructed and three existing models had been utilised.

The three existing models were:

- Dereham Stream through Dereham, modelled in 1991 by Mott MacDonald;
- River Thet and Little Ouse at Thetford, modelled by Royal Haskoning in 2000;
- River Wensum and Wendling Beck, modelled by Babtie, Brown and Root in 2003.

The six new models were constructed using the iSIS software. They were all simple steady-state models constructed using existing cross-section survey data provided by the EA. Where necessary, the cross-sections were extended onto the floodplain using the terrain data. Table D.1 summarises the hydraulic modelling which had been undertaken for Stage 2 of the study.

Table D.1: Summary of New Hydraulic Models

River	Study Area	Model Length (km)	Upstream Limit	Downstream Limit	Survey Date	Cross Section Spacing (m)
Tud	Dereham	2.3	5981 3109	6002 3109	1993	250
Watton Br	Watton	4.9	5937 3019	5896 3006	1991	200
Wissey	Necton	3.2	5888 3082	5873 3084	1992	200
Blackwater	Shipdham	1.5	5951 3067	5958 3061	1993	250
Tud	Mattishall	4.5	6026 3122	6066 3127	1993	250
Thet	East Harling	3.1	5981 2859	5983 2878	1993-1994	200

In Stage 3 of the study (2007), newer models commissioned by the EA between 2005 and 2007 have been used wherever possible:

- The River Tud model built by JBA for BBR in 2005 superseded the River Tud at Dereham and the River Tud at Mattishall models built by MM in 2005.
- The River Upper Yare model built by JBA for BBR in 2005 superseded the River Blackwater at Shipdham built by MM in 2005.
- The River Thet and River Little Ouse at Thetford built by Halcrow in 2006 superseded the River Thet and River Little Ouse at Thetford built by Royal Haskoning in 2000.

All the models which have been used for the Stage 3 of the Study are described in detail in Sections D.1 – D.8 below.

As part of the SFRA update (Stage 3), the 1 in 20-year event has been modelled to re-delineate the extent of the functional floodplain, as defined in PPS25. For this purpose, 1 in 20-year model inflows have been estimated using the FEH method, and not the Re-FEH method. The Re-FEH method is the latest update of the FEH method, which produces lower flow estimates when using the rainfall-runoff module. However this latest update of FEH has not been used in order to be consistent with the work undertaken in 2005 and the existing 100-year outline. This is a conservative choice.

D.1 Watton Brook at Watton

The model extends from Ovington Road Bridge for nearly 5 km to the downstream edge of Watton.

D.1.1 Hydrology

At the downstream limit the catchment area is 42 km^2. The design inflows were calculated at this point.

The FEH rainfall-runoff method has been adopted to calculate design flows as there are no gauging stations on Watton Brook and it gives more conservative flows than the statistical method. A critical storm duration of 15 hours was utilised. This gives the following peak design flows:

5%	15.0 m^3/s
1%	23.0 m^3/s

D.1.2 Hydraulics

The model nodes are spaced at 200 metres. The model has a total of 44 nodes, of which five are structures. These are all bridges modelled with the iSIS bridge units. The floodplain is modelled with extended cross sections extracted from the LiDAR data.

The channel survey extends as far upstream as Willow Farm. In order to extend the model further upstream to Ovington Road Bridge, three channel cross sections were surveyed. These measurements were integrated into the model through assigning them bank top levels, equivalent to the LiDAR data extended section taken at the same location. Therefore, the water levels for the upstream reach of the model are less reliable.

There is a single, normal depth downstream boundary at section 10.991, a farm access bridge.

D.1.3 Mapping

The modelled water levels from the new iSIS model were mapped at each of the node locations.

These levels were converted to a water surface taking into account floodplain flow and ineffective flow in built-up areas. Discontinuities were included at railway and road embankments.

The water surface was then intersected with a DTM built from a combination of LiDAR and SAR data. LiDAR are available for 95% of the Watton area. For the remaining 5%, IFSAR data have been used, after adjusting them by -0.4m so that they match the LiDAR data, as discussed in Section 2.1 of this report.

The resulting flood extents were reviewed and mapped. The review process was conducted using information from the iSIS models in conjunction with O.S. mapping, topographic levels and hillshade. As the unfiltered LiDAR has been used, some discontinuities were due to LiDAR returns from the tops of housing or trees. These were identified in the review process and where appropriate included within the flood envelope.

The 100-year outline obtained with this modelling technique shows a larger extent than the 1000-year outline from the EA Flood Zones. As discussed in Section 2.3 of the report, this kind of inconsistency was expected, as the methods used to derive the outlines for the SFRA and for EA Flood Zones are different. The SFRA uses results from detailed hydrological and hydraulic modelling of all Main Rivers to obtain flood levels, and combines these with ground level information predominantly sourced from LiDAR techniques giving a vertical accuracy of +/- 15cm. For the EA Flood Zone maps, the basic zoning has been based on a relatively coarse national hydrological model combined with a new national DTM sourced from IFSAR techniques, giving a vertical accuracy of +/- 70cm. MM therefore believes that the new 100-year outline obtained with the detailed modelling of the Watton Brook is more representative than the 1000-year outline from the EA Flood Zones.

D.2 River Wissey at Necton

The River Wissey is modelled from Holme Hale Bridge downstream to Erneford Bridge, a length of 3.2 km.

D.2.1 Hydrology

At the downstream limit the catchment area is 40 km^2. The design inflows were calculated at this location.

The FEH rainfall-runoff method has been adopted to calculate design flows as there are no gauging stations this far upstream on the River Wissey, and it gives slightly more conservative flows than the statistical method. A critical storm duration of 15 hours was utilised. This gives the following peak design flows:

5%	15.3 m^3/s
1%	23.5 m^3/s

D.2.2 Hydraulics

The model nodes are spaced at 200 metres. The model has a total of 21 nodes, of which 2 are structures. Are all bridges modelled with the iSIS USBPR bridge units. The floodplain is modelled with extended cross sections extracted from the LiDAR or SAR data.

There is a single, normal depth downstream boundary located at Erneford Bridge.

D.2.3 Mapping

The modelled water levels from the new iSIS model were mapped at each of the node locations.

These levels were converted to a water surface taking into account floodplain flow. Discontinuities were included at road embankments.

The water surface was then intersected with a DTM built from a combination of LiDAR and SAR data. LiDAR are available for 5% of the Necton area. For the remaining 95%, IFSAR data have been used, after adjusting them by -0.4m so that they match the LiDAR data, as discussed in Section 2.1 of this report.

The resulting flood extents were reviewed and mapped. The review process was conducted using information from the iSIS models in conjunction with O.S. mapping, topographic levels and hillshade. As the unfiltered LiDAR has been used, some discontinuities were due to LiDAR returns from the tops of housing or trees. These were identified in the review process and where appropriate included within the flood envelope.

D.3 River Thet at East Harling

A 3.1 km length model has been constructed of the River Thet. This extends from 250m downstream of the railway to near The Paddocks.

D.3.1 Hydrology

At the downstream limit the catchment area is 266 km^2. Design inflows have been calculated using the statistical method at the gauging station at Brigham, 3 km downstream. The catchment area at the gauging station is 275 km^2.

There are 35 years of record at Bridgham, with the largest recorded flow being around 15 m^3/s. Single site analysis was undertaken and this gave a 1% flow of 19.0 m^3/s. To confirm this, analysis was undertaken for the River Thet at Melford, which is located further downstream and has a catchment area of 312 km^2. This gauging station has an out-of-bank rating curve which shows a good fit to the check spot gaugings and is considered more reliable for flood flows than the Thet at Bridgham. There are 40 years of record at the Melford site. Single site analysis gave a 1% flow of 21.5 m^3/s at Melford, which when scaled down to take account of catchment area gives a 1% flow of 19.0 m^3/s at Bridgham. Therefore, the two sites correspond well, which increases confidence in the calculated values.

Therefore, the following peak design flows were adopted:

5%	14.8 m^3/s
1%	19.0 m^3/s

D.3.2 Hydraulics

The model nodes are spaced at 200 metres. The model has a total of 34 nodes, of which 3 are structures. The structures are all located where the River Thet passes under Church Road. At this location the channel splits into two due the location of a mill. A side weir takes the main channel out of the mill pond and under a flat single span bridge under Church Road. The remainder of the channel passes through an arch bridge under the road. Survey of any mill structures is not available, however SAR data was utilised to synthesise some additional cross sections in this area. The two channels rejoin about 100 metres downstream of Church Road.

The floodplain is modelled with extended cross sections extracted from the SAR data.

There is a single, normal depth downstream boundary at channel section 16.800.

D.3.3 Mapping

The modelled water levels from the new iSIS model were mapped at each of the node locations.

These levels were converted to a water surface taking into account floodplain flow and ineffective flow in built-up areas. Discontinuities were included at road embankments.

The water surface was then intersected with a DTM built from IFSAR data, as there is no LiDAR coverage in East Harling. IFSAR data have been adjusted by -0.4m so that they match the LiDAR data, as discussed in Section 2.1 of this report.

The resulting flood extents were reviewed and mapped. The review process was conducted using information from the iSIS models in conjunction with O.S. mapping and topographic levels.

D.4 Dereham Stream at Dereham

Dereham Stream was modelled by Mott MacDonald in 1991 using HYDRO-1D. The original study was undertaken for King's Lynn Consortium of IDBs to consider capacity of the channel and look at flood alleviation options. The model has since been adapted to reflect several changes in the catchment, including a new culvert at Larners Road.

D.4.1 Hydrology

The original model was constructed using FSR techniques. The hydrology has been updated as part of this study to use FEH techniques. As mentioned earlier, the FEH CD ROM does not properly define the catchment boundaries in Dereham. These were modified and the FEH statistical method was utilised to calculate design inflows for the 5% and 1% events. For the purpose of this study, the catchment was split into a more urban upstream area of 1.5 km^2 and a more rural downstream area of 8 km^2.

This gave the following design inflows, which are broadly comparable to those used as the inflow to the Wensum model for the Strategy Study once the error in the catchment areas has been changed:

	Upstream	Downstream
5%	1.0 m^3/s	2.96 m^3/s
1%	1.4 m^3/s	4.2 m^3/s

However these inflows have been further adjusted so that the water levels obtained with the Dereham Stream model match recorded events. The final inflows which have been used in the model are:

	Upstream	Downstream
5%	1.45 m^3/s	3.98 m^3/s
1%	1.75 m^3/s	4.75 m^3/s

D.4.2 Hydraulics

The model network has remained unchanged as we have no new survey data for this stream. The model inflows were changed to reflect the design flows estimated above, and these were distributed so that the flow increased gradually down the stream.

The modelled levels produced are comparable to the design levels produced in the original study.

D.4.3 Mapping

Cross sections were plotted into GIS from the maps in the original reports. The levels for the design events were attached to each of these cross sections. These levels were converted to a water surface taking into account floodplain flow and ineffective flow in built-up areas. Discontinuities were included at railway and road embankments.

The water surface was then intersected with a DTM built from a combination of LiDAR and SAR data. LiDAR are available for approximately 90% of the Dereham area. For the remaining 10%, IFSAR data have been used, after adjusting them by -0.4m so that they match the LiDAR data, as discussed in Section 2.1 of this report.

The resulting flood extents were reviewed and mapped. The review process was conducted using information from the iSIS models in conjunction with O.S. mapping and topographic levels. As the unfiltered LiDAR has been used, some discontinuities were due to LiDAR returns from the tops of housing or trees. These were identified in the review process and where appropriate included within the flood envelope.

D.5 River Thet and Little Ouse River at Thetford

Halcrow carried out a Standard of Protection Study in 2006 for the Thet and the Little Ouse in Thetford. A 1D hydraulic model was constructed using iSIS to model up to the 200-year event, and a further 2D computer model prepared using Tuflow to model the 1000-year event. The output from this study has been utilised in the SFRA to create new fluvial flood extent maps in Thetford.

D.5.1 Hydrology

Hydrological inflow boundaries were estimated by Halcrow for the 1 in 5, 10, 25, 50, 75, 100, 200 and 1000-year flood events, the methodology comprised:

- Statistical analysis of annual maxima of the Rectory Bridge, Euston and Melford Bridge flow gauging stations
- Determination of hydrograph average shape from gauges records
- Production of inflow design hydrographs by scaling the average shape to fit the statistical analysis
- Determination of the average phasing of the input hydrographs from the Thet and Little Ouse from analysis of observed events.

MM estimated the hydrological inflow boundary for the 1 in 100-year with climate change scenario by scaling the 100-year hydrograph from Halcrow by 1.2.

D.5.2 Hydraulics

The iSIS 1D hydraulic model was built from topographic survey and LiDAR data. It comprises 8.5 km of in-channel modelling, linked together via floodplain spills and storage areas. The model has a total of 467 nodes. There is a constant elevation downstream boundary at Abbey Heath weir.

D.5.3 Mapping

Halcrow produced 100-year and 1000-year flood outlines, which have been used for the SFRA.

Additionally MM produced the 25-year and 100-year with climate change outlines to inform the SFRA. The 25-year flood outline was used to produce the boundaries of the Functional Floodplain Zone, instead of the 20-year flood outline as recommended in PPS25. This conservative decision was taken in consultation with the Breckland District Council because the 25-year water levels were readily available and can be expected to be very similar to the 20-year water levels.

Cross sections were plotted into GIS using geographical referencing data from the .gxy iSIS file provided by Halcrow. The cross-section locations were reviewed to ensure consistency with the structure locations. The locations of the modelled storage areas were also provided by Halcrow and reviewed by MM. The levels for the design events were attached to each of the cross sections and storage areas. These levels were converted to a water surface taking into account floodplain flow and ineffective flow in built-up areas. Discontinuities were included at railway and road embankments.

The water surface was then intersected with a DTM entirely built from LiDAR data. The resulting flood extents were reviewed and mapped, particularly to ensure consistency with the existing 100-year and 1000-year flood outlines. The review process was conducted using information from the iSIS models in conjunction with O.S. mapping and topographic levels. As the unfiltered LiDAR has been used, some discontinuities were due to LiDAR returns from the tops of housing or trees. These were identified in the review process and where appropriate included within the flood envelope.

D.6 River Wensum and Wendling Beck

Babtie, Brown and Root (BBR) carried out a Strategy Study in 2003 for the Upper River Wensum. It covers the Upper River Wensum and its major tributaries the Whitewater and Wendling Beck. A hydraulic model was constructed using iSIS to predict flood levels in the study area. The output from this study has been utilised in the SFRA to create flood extent maps for Wendling Beck to the north of Dereham and Wendling Beck and the River Wensum around North Elmham.

D.6.1 Hydrology

Hydrological analysis was carried out for the Strategy Study by JBA Consulting. The study used the FEH statistical method to calculate inflows as it was clear that the rainfall-runoff method overestimated flows in this catchment.

The study calculated inflows for a range of return periods, including the 1% and 4% events.

D.6.2 Hydraulics

The iSIS 1D hydraulic model was built from topographic survey and LiDAR data. Depending on its characteristics, the floodplain has been represented by either extended cross-sections or reservoir units. The total length of modelled watercourses is 86 km and the number of nodes in the model is 1,325 (including spills and flood storage areas as well as channel cross sections and structures). Cross sections are spaced at 250m intervals.

D.6.3 Mapping

BBR produced the 25-year, 100-year and 100-year with climate change flood outlines, which have been used for the SFRA. The 25-year flood outline was used to produce the boundaries of the Functional Floodplain Zone, instead of the 20 year flood outline as recommended in PPS25. This conservative decision was taken in consultation with the Breckland District Council because the 25 year flood outline was readily available and can be expected to be very similar to the 20-year flood outline.

D.7 River Upper Yare

Babtie, Brown and Root (BBR) carried out a Flood Risk Study in 2005 for the River Yare. It covers the River Yare, the River Tas and associated Main River branches and Critical Ordinary Watercourses (COWs). A hydraulic model was constructed by JBA Consulting for the flood risk study using iSIS to predict flood levels in the study area. The output from this study has been utilised to create flood extent maps of the River Yare throughout the SFRA area. The River Yare is also called the River Blackwater in its upstream part.

D.7.1 Hydrology

The study used the FEH statistical method to calculate inflows as it was clear that the rainfall-runoff method overestimated flows in this catchment.

The study calculated inflows for a range of return periods, including the 1% and 4% events.

D.7.2 Hydraulics

The upstream part of the River Yare corresponding to the portion within the SFRA area has been modelled in steady state. Flow within the river channel is represented using cross sections. In the steady-state models, all floodplains are represented using extended cross sections. This is a conservative approach as it assumes that there is an unlimited volume of water available to fill any storage areas on the floodplain. LiDAR and Nextmap elevation data were used to represent areas outside the channel, together with spot level survey in the villages of Mulbarton and Wacton where no LiDAR data was available. The typical cross section spacing is relatively wide, at 250m.

D.7.3 Mapping

BBR produced the 25-year, 100-year and 100-year with climate change flood outlines, which have been used for the SFRA. The 25-year flood outline was used to produce the boundaries of the Functional Floodplain Zone, instead of the 20-year flood outline as recommended in PPS25. This conservative decision was taken in consultation with the Breckland District Council because the 25-year flood outline was readily available and can be expected to be very similar to the 20-year flood outline.

D.8 River Tud

Flood risk modelling of the River Tud model has been undertaken by Babtie, Brown and Root in 2005 for the EA. A hydraulic model was constructed using iSIS to predict flood levels in the study area. The steady state output from this study has been utilised to create flood extent maps of the River Tud all the way through the SFRA area, including Mattishall and Dereham. The River Tud flood mapping report has not been made available to MM, and for this reason MM was not able to provide detailed information on the hydrology and the hydraulics of the model.

The examination of the modelling files shows that BBR produced two different versions of the model, a steady-state version and an unsteady one. In the steady-state version, all floodplains are represented using extended cross sections. This is a conservative approach as it assumes that there is an infinite volume of water available to fill any storage areas on the floodplain. In the unsteady version of the model, the floodplain is represented with reservoirs units. MM opted for the conservative approach.

D.8.1 Mapping

MM produced the 25-year, 100-year and 100-year with climate change outlines of the River Tud within the SFRA area, including Mattishall and Dereham. The 25-year flood outline was used to produce the boundaries of the Functional Floodplain Zone, instead of the 20-year flood outline as recommended in PPS25. This conservative decision was taken in consultation with the Breckland District Council because the 25-year water levels were readily available and can be expected to be very similar to the 20-year water levels.

Cross sections were plotted into GIS using geographical referencing data from a MapInfo GIS layer provided by BBR. The levels for the design events were attached to each of the cross sections. These levels were converted to a water surface taking into account floodplain flow and ineffective flow in built-up areas. Discontinuities were included at railway and road embankments.

The water surface was then intersected with a DTM entirely built from LiDAR data. The resulting flood extents were reviewed and mapped. The review process was conducted using information from the iSIS model in conjunction with O.S. mapping and topographic levels. As the unfiltered LiDAR has been used, some discontinuities were due to LiDAR returns from the tops of housing or trees. These were identified in the review process and where appropriate included within the flood envelope. In addition, ground elevations used at the upstream end of the iSIS model were found to be 4 m higher than in the DTM, leading to unrealistically large predicted flood extents for the upstream reach of the River Tud. These extents have been adjusted manually.

Appendix E: Estimation of the additional runoff generated by large proposed developments

The methodology described in the SUDS Manual (CIRIA C697, 2007) was used to provide initial estimates of the peak runoff rates and volumes from the proposed development sites and their greenfield equivalents.

The following data relating to the proposed developments have been provided by the Breckland District Council:

- Developments types, residential or employment
- Locations of the developments
- Indicative density of the proposed residential developments
- Range of number of houses for the proposed residential developments
- Indicative areas of the proposed employment developments.

The types and locations of the proposed developments are shown on the maps included in Appendices A and B.

Owing to the uncertainty related to the density and number of houses of the proposed residential developments, MM have estimated runoff rates and volumes for a range of housing densities and number of houses centred on the values provided by the Council. The housing density, number of houses and employment development areas which have been used to perform the runoff calculations are shown in Table E.1.

Regulatory authorities normally require the **developed rate of runoff** to be not greater than the greenfield runoff rate for a range of annual flow rates probabilities up to 1% probability flow. MM estimated the rate of runoff for the 100% and the 1% probabilities events. Additional flow rate probabilities should be considered when producing surface water strategies. The **runoff volume** has been estimated on the basis of the 100 year, 6 hour rainfall event, which is recommended in the Preliminary Rainfall Runoff Management guidance and in the SUDS Manual for the assessment of the long-term storage.

As required by PPS25, climate change impacts on the runoff have been assessed. Owing to the current uncertainty with regards to the type of development and its associated lifetime, it was agreed with Breckland District that two climate change scenarios for the runoff rate would be considered:

- From 2055 to 2085: +20% in the peak rainfall intensity
- From 2085 to 2115: +30% in the peak rainfall intensity

E.1 Greenfield Runoff

E.1.1 Estimating Greenfield Runoff Rates

The size of the development determines the method that should be used to estimate runoff. As all the proposed development areas in Breckland are less than 200 ha, the Institute of Hydrology Report 124 *Flood estimation for small catchments* has been used to determine peak greenfield runoff rates.

The catchment mean annual peak flow can be determined from the following equation:

$$QBAR_{rural} = 0.00108 \times AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

$QBAR_{rural}$	=	Catchment mean annual peak flow (m^3/s)
AREA	=	Development area (km^2)
SAAR	=	Standard average annual rainfall for 1941 to 1970 (mm)
SOIL	=	Soil index

Residential developments areas were not directly provided by the Council and have been estimated using the following formula:

$$AREA = \frac{H}{d}$$

d	=	Density of housing (no. of houses / ha),
H	=	Number of houses

Values for SAAR and SOIL for each proposed development area were obtained from the *Wallingford Procedure for Europe* (Kellagher, 2000). However, as these values within each settlement were very similar, an average value for all the proposed developments within each settlement has been used. These values are shown in Table E.2.

To estimate the peak flow rates for the 1-year and 100-year return periods, the UK Growth Curve Factors from FSSR 16 (IH, 1985) were applied to the $QBAR_{rural}$. The growth curve factors are dependant on the geographical location within UK. It was determined that the whole Breckland District was located within the Hydrometric Area 5.

Final estimates of greenfield peak flow rates are shown in Tables E.1 and E.2 for the proposed residential developments and employment developments respectively.

E.1.2 Estimating Greenfield Runoff Volumes

The following equation has been used to calculate the greenfield runoff volumes for each development site for the 1-year and 100-year events:

$$Greenfield \quad Runoff \quad Volume = RD \times A \times PR_g$$

RD	=	Rainfall Depth (mm)
A	=	Proposed Development Area (m^2)
PR_g	=	Total Percentage Runoff for the greenfield catchment, assumed to be equal to SPR

Rainfall depths have been estimated using the Depth Duration Frequency model (DDF) included in the FEH CD-ROM. As the proposed development areas are mostly small, it has been assumed that the rainfall frequency at a point was valid for the entire proposed development areas and that no areal reduction factor was needed. Rainfall depth estimates are shown in Table E.3.

Final estimates of greenfield runoff volumes are shown in Tables E.3 and E.4 for the proposed residential developments and employment developments respectively.

E.2 Development Runoff

E.2.1 Estimating Development Runoff Rates

The *Modified Rational Method* has been used to calculate the rate of runoff from the proposed development sites, using the following equation:

$$Q_p = 3.61 \times C_v \times I \times A_i$$

Q_p = Peak Runoff in (l/s)
C_v = Volumetric Runoff Coefficient
I = Rainfall Intensity (mm/hr)
A_i = Impermeable Area (ha)

The maximum rainfall intensity (I) has been obtained by using the shortest storm duration for which the whole development area contributes to peak runoff. This has been assumed to be 15 minutes as the DDF model is not valid for shorter durations. Rainfall intensity estimates are shown in Table E.3.

The volumetric runoff coefficient has been calculated using the following equation:

$$C_V = \frac{PR_d}{PIMP}$$

PR_d = Percentage Runoff for the developed catchment
PIMP = Percentage of Impermeable area

Owing to the current uncertainty in the PIMP values for the proposed employment developments, a 60%-90% range has been assessed.

For housing developments, the percentage of impermeable area has been calculated as a function of the density of each development by assuming a standard impermeable area per house of 0.015ha, including roofing and surrounding streets. This resulted in the following equation for percentage of impermeable area:

$$PIMP = 0.015 \times d \times 100$$

d = Density of housing (no. of houses / ha)

The percentage runoff of the proposed developed sites has been calculated using the following equation from the *Fixed Wallingford Procedure UK model*:

$$PR_d = 0.829PIMP + 25SOIL + 0.078UCWI - 20.7$$

UCWI = Urban Catchment Wetness Index

The UCWI for each catchment has been derived from the figure relating UCWI to SAAR in the Wallingford Procedure, using the conservative winter profile. UCWI values are shown in Table E.2.

Final estimates of "developed peak flow rates" are shown in Tables E.4 and E.5 for the proposed residential developments and employment developments respectively.

E.2.2 Estimating Long-Term Storage Volumes

Long-term storage aims specifically to address the additional volume of runoff caused by the development. The basis for sizing this storage is the 100 year, 6 hour rainfall event. The intention of long-term storage is to allow the volume equal to the greenfield runoff to discharge at greenfield rate, while the additional runoff should be discharged as infiltration or very low rate (2 l/s/ha). The objective is to protect the river during times of extreme flooding.

The following equation has been used to estimate the runoff volume from the proposed development sites:

$$Developed\ \ Runoff\ \ Volume = RD \times A \times \left[\frac{PIMP}{100}(\alpha 0.8) + \left(1 - \frac{PIMP}{100}\right)\left(\beta.\frac{SPR}{100}\right)\right]$$

RD	=	Rainfall Depth for the 100-year return period 6 hour event
α	=	Proportion of paved area draining to the network or directly to the river
β	=	Proportion of pervious area draining to the network or directly to the river
SPR	=	Surface Percentage Runoff obtained from the FEH CD-ROM

Both α and β have been taken as 1 in order to be conservative.

SPR values are shown in Table E.2.

The long-term storage volume estimates have been obtained by subtracting the greenfield runoff volumes from the developed runoff volumes for the 100 year, 6 hour rainfall event. Final estimates of the long-term storage volumes required are shown in Tables E.6 and E.7 for the proposed residential developments and employment developments respectively.

Table E.1: Data related to the scale of developments

Settlement	Type	Proposed residential Developments				Proposed Employment Developments
		Housing Density (houses/ha)		Houses Number		Areas (ha)
		MIN	MAX	MIN	MAX	
Thetford	growth point	35	45	4000	6000	38
Attleborough	town	32	42	1000	4000	10
Dereham	town	32	42	500	1000	8
Swaffham	town	32	42	480	720	5
Watton	town	32	42	280	420	3
Shipdham	village	25	35	80	120	0
Great Ellingham	village	25	35	40	60	0
Harling	village	25	35	40	60	0
Narborough	village	25	35	40	60	0
Banham	village	25	35	0	50	0
Mattishall	village	25	35	0	50	0
Necton	village	25	35	0	50	0
North Elmham	village	25	35	0	50	0
Old Buckenham	village	25	35	0	50	0
Saham Toney	village	25	35	0	50	0
Swanton Morley	village	25	35	0	50	0
Weeting	village	25	35	0	50	0

Table E.2: Catchment Descriptors

Settlement	SPR (%)	SAAR (mm/year)	$UCWI_{winter}$	SOIL
Thetford	9	600	121	0.15
Attleborough	32	651	126	0.40
Dereham	35	688	130	0.40
Swaffham	12	672	128	0.15
Watton	34	650	126	0.40
Shipdham	37	710	132	0.40
Great Ellingham	36	650	126	0.40
Harling	6	620	123	0.40
Narborough	8	640	125	0.15
Banham	35	630	124	0.40
Mattishall	37	645	126	0.40
Necton	31	690	130	0.40
North Elmham	34	645	126	0.15
Old Buckenham	39	640	125	0.40
Saham Toney	30	650	126	0.40
Swanton Morley	35	665	128	0.30
Weeting	5	630	124	0.15

Table E.3: Rainfall Estimates

Settlement	Rainfall Depth (mm) Storm Duration = 600 min			Rainfall Intensity (mm/hour) Storm Duration = 15 min			
	RD_{100y}	$RD_{100y+20\%}$	$RD_{100y+30\%}$	I_{1y}	I_{100y}	$I_{100y+20\%}$	$I_{100y+30\%}$
Thetford	72	86	93	31	155	186	202
Attleborough	70	84	91	31	151	182	197
Dereham	69	83	90	31	156	187	203
Swaffham	67	80	87	33	156	187	203
Watton	69	83	90	31	157	189	204
Shipdham	72	86	93	31	156	188	203
Great Ellingham	72	87	94	30	152	182	197
East Harling	70	84	91	31	156	187	203
Narborough	72	87	94	31	146	176	190
Banham	70	84	90	32	157	188	204
Mattishall	70	84	91	32	154	184	200
Necton	70	83	90	32	152	182	197
North Elmham	73	88	95	30	148	178	193
Old Buckenham	69	82	89	32	153	184	199
Saham Toney	69	82	89	32	159	191	206
Swanton Morley	69	83	90	31	156	187	203
Weeting	74	88	96	30	148	177	192

Key	
RD100y	Rainfall depth for the 100 year return period event of 600 minutes duration
$I_{100y+20\%}$	Rainfall intensity for the 100 year return period event of 15 minutes duration, plus 20% to take into account the impact of climate change up to 2055
$I_{100y+20\%}$	Rainfall intensity for the 100 year return period event of 15 minutes duration, plus 20% to take into account the impact of climate change up to 2115

Table E4: Peak Runoff for Proposed Residential Development Sites and Greenfield Equivalents

GREENFIELD

	H_{min} / d_{min} ($A_{i.min}$, $PIMP_{min}$)					H_{max} / d_{min} ($A_{i.max}$, $PIMP_{max}$)					H_{min} / d_{max} ($A_{i.min}$, $PIMP_{max}$)					H_{max} / d_{max} ($A_{i.max}$, $PIMP_{max}$)				
Settlements	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)
Thetford	26.7	125.6	150.7	163.3	1.1	38.3	180.2	216.2	234.3	1.1	21.3	100.4	120.5	130.6	1.1	30.6	144.1	172.9	187.3	1.1
Attleborough	77.8	366.1	439.4	476.0	11.7	267.3	1257.4	1508.9	1634.7	10.1	61.1	287.4	344.9	373.7	12.1	209.8	987.1	1184.6	1283.3	10.4
Dereham	44.8	210.7	252.9	273.9	13.5	83.0	390.5	468.6	507.7	12.5	35.2	165.4	198.5	215.1	13.9	65.2	306.6	367.9	398.5	12.9
Swaffham	5.0	23.5	28.2	30.6	1.6	7.2	33.7	40.5	43.9	1.5	3.9	18.5	22.2	24.0	1.6	5.6	26.5	31.8	34.4	1.5
Watton	25.0	117.7	141.3	153.0	13.5	35.9	168.9	202.6	219.5	12.9	19.6	92.4	110.9	120.1	13.9	28.2	132.6	159.1	172.3	13.3
Shipdham	11.3	53.3	64.0	69.3	16.7	16.3	76.5	91.8	99.4	15.9	8.4	39.5	47.4	51.4	17.3	12.1	56.7	68.0	73.7	16.5
Great Ellingham	5.5	25.9	31.1	33.7	16.2	7.9	37.2	44.7	48.4	15.5	4.1	19.2	23.1	25.0	16.8	5.9	27.6	33.1	35.9	16.1
Harling	5.2	24.6	29.5	31.9	15.3	7.5	35.2	42.3	45.8	14.7	3.9	18.2	21.8	23.7	15.9	5.5	26.1	31.3	33.9	15.2
Narborough	0.6	3.0	3.6	3.9	1.9	0.9	4.4	5.2	5.7	1.8	0.5	2.2	2.7	2.9	2.0	0.7	3.2	3.9	4.2	1.9
Banham	0.0	0.0	0.0	0.0	0.0	6.5	30.5	36.6	39.7	15.3	0.0	0.0	0.0	0.0	0.0	4.8	22.6	27.1	29.4	15.8
Mattishall	0.0	0.0	0.0	0.0	0.0	6.7	31.4	37.6	40.8	15.7	0.0	0.0	0.0	0.0	0.0	4.9	23.2	27.9	30.2	16.3
Necton	0.0	0.0	0.0	0.0	0.0	7.2	33.9	40.7	44.1	17.0	0.0	0.0	0.0	0.0	0.0	5.3	25.2	30.2	32.7	17.6
North Elmham	0.0	0.0	0.0	0.0	0.0	0.8	3.7	4.5	4.9	1.9	0.0	0.0	0.0	0.0	0.0	0.6	2.8	3.3	3.6	1.9
Old Buckenham	0.0	0.0	0.0	0.0	0.0	6.6	31.1	37.3	40.4	15.5	0.0	0.0	0.0	0.0	0.0	4.9	23.0	27.6	29.9	16.1
Saham Toney	0.0	0.0	0.0	0.0	0.0	6.7	31.6	38.0	41.1	15.8	0.0	0.0	0.0	0.0	0.0	5.0	23.5	28.2	30.5	16.4
Swanton Morley	0.0	0.0	0.0	0.0	0.0	3.7	17.4	20.9	22.6	8.7	0.0	0.0	0.0	0.0	0.0	2.7	12.9	15.5	16.8	9.0
Weeting	0.0	0.0	0.0	0.0	0.0	0.8	3.6	4.4	4.7	1.8	0.0	0.0	0.0	0.0	0.0	0.6	2.7	3.2	3.5	1.9

DEVELOPED

	H_{min} / d_{min} ($A_{i.min}$, $PIMP_{min}$)					H_{max} / d_{min} ($A_{i.max}$, $PIMP_{max}$)					H_{min} / d_{max} ($A_{i.min}$, $PIMP_{max}$)					H_{max} / d_{max} ($A_{i.max}$, $PIMP_{max}$)				
Settlements	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)
Thetford	4647	23058	27669	29975	202	6971	34587	41504	44963	202	4863	24127	28952	31365	271	7294	36190	43428	47047	211
Attleborough	1366	6649	7979	8644	213	5465	26597	31916	34576	213	1374	6685	8022	8690	281	5495	26739	32087	34760	214
Dereham	692	3452	4143	4488	221	1383	6904	8285	8976	221	694	3464	4157	4503	291	1388	6928	8313	9006	222
Swaffham	582	2774	3329	3606	185	873	4161	4993	5410	185	611	2914	3497	3789	255	917	4371	5246	5683	194
Watton	384	1932	2318	2511	221	577	2897	3477	3767	221	386	1942	2330	2524	291	580	2913	3495	3787	222
Shipdham	111	554	665	721	173	166	832	998	1081	173	111	556	668	723	243	167	835	1002	1085	174
Great Ellingham	53	265	317	344	165	80	397	476	516	165	53	267	320	347	233	80	400	480	520	167
Harling	54	270	324	351	169	81	405	486	527	169	55	273	328	355	239	82	409	491	532	171
Narborough	42	202	242	263	126	64	303	364	394	126	46	219	263	285	192	69	329	395	428	137
Banham	0	0	0	0	0	69	340	408	442	170	0	0	0	0	0	69	344	412	447	172
Mattishall	0	0	0	0	0	69	335	402	436	168	0	0	0	0	0	70	338	405	439	169
Necton	0	0	0	0	0	70	334	401	434	167	0	0	0	0	0	70	336	403	437	168
North Elmham	0	0	0	0	0	51	257	308	334	128	0	0	0	0	0	56	279	334	362	139
Old Buckenham	0	0	0	0	0	70	333	400	433	167	0	0	0	0	0	70	336	404	437	168
Saham Toney	0	0	0	0	0	69	346	416	450	173	0	0	0	0	0	70	349	419	454	175
Swanton Morley	0	0	0	0	0	63	314	377	408	157	0	0	0	0	0	65	324	389	422	162
Weeting	0	0	0	0	0	52	254	304	330	127	0	0	0	0	0	56	276	331	359	138

Key	
H_{min} / d_{min} ($A_{i.min}$, $PIMP_{min}$)	Minimum number of houses (H_{min}) is equivalent to a minimum impervious area (A_{imin}); Minimum density of houses (d_{min}) is equivalent to minimum percentage impervious area ($PIMP_{min}$)
Q_{p1y} (l/s)	Peak runoff for the 1 year return period storm
Q_{p100y} (l/s)	Peak runoff for the 100 year return period storm
$Q_{p100y+20\%}$ (l/s)	Peak runoff for the 100 year return period storm plus 20% to take into account the impact of climate change up to 2055
$Q_{p100y+30\%}$ (l/s)	Peak runoff for the 100 year return period storm plus 30% to take into account the impact of climate change up to 2115

Table E5: Peak Runoff for Proposed Employment Development Sites and Greenfield Equivalents

	GREENFIELD				
Settlements	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)
Thetford	10.0	47.1	56.6	61.3	0.3
Attleborough	28.2	132.8	159.4	172.7	3.7
Dereham	24.7	116.1	139.4	151.0	4.1
Swaffham	1.9	8.8	10.6	11.5	0.5
Watton	9.7	45.4	54.5	59.0	4.3

	DEVELOPED									
	Minimum					Maximum				
Settlements	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)	Q_{p1y} (l/s)	Q_{p100y} (l/s)	$Q_{p100y+20\%}$ (l/s)	$Q_{p100y+30\%}$ (l/s)	Q_{p100y} (l/s/ha)
Thetford	1812	8990	10789	11688	237	2879	14285	17142	18571	376
Attleborough	549	2672	3206	3473	267	828	4031	4837	5241	403
Dereham	444	2216	2659	2880	277	668	3336	4003	4337	417
Swaffham	253	1205	1446	1566	241	400	1906	2287	2477	381
Watton	165	832	998	1081	277	250	1255	1506	1631	418

Table E6: Additional Runoff Volume due to Residential Development

PRESENT DAY

Settlements	H_{min} / d_{min} ($A_{i,min}$, $PIMP_{min}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{min} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{min} / d_{max} ($A_{i,min}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{max} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	7731	68	38088	333	30357	266	11596	68	57132	333	45536	266	6013	68	36370	409	30357	342	9019	68	54555	409	45536	342
Attleborough	7049	226	12041	385	4993	160	28195	226	48165	385	19970	160	5371	226	10363	435	4993	210	21482	226	41452	435	19970	210
Dereham	3763	241	6108	391	2345	150	7525	241	12215	391	4690	150	2867	241	5212	438	2345	197	5734	241	10424	438	4690	197
Swaffham	1170	78	4463	298	3293	220	1755	78	6694	298	4939	220	891	78	4184	366	3293	288	1337	78	6276	366	4939	288
Watton	2087	239	3418	391	1331	152	3131	239	5127	391	1996	152	1590	239	2921	438	1331	200	2386	239	4381	438	1996	200
Shipdham	841	263	1213	379	372	116	1262	263	1820	379	558	116	601	263	973	426	372	163	902	263	1459	426	558	163
Great Ellingham	414	259	605	378	191	119	621	259	907	378	286	119	296	259	487	426	191	167	444	259	730	426	286	167
Harling	70	44	380	237	310	194	105	44	569	237	465	194	50	44	360	315	310	271	75	44	540	315	465	271
Narborough	91	57	403	252	313	195	136	57	605	252	469	195	65	57	377	330	313	273	97	57	566	330	469	273
Banham	0	0	0	0	0	1	489	245	723	362	234	117	0	0	0	0	0	0	349	245	584	409	234	164
Mattishall	0	0	0	0	0	0	512	256	739	370	227	114	0	0	0	0	0	0	366	256	593	415	227	159
Necton	0	0	0	0	0	0	431	216	687	343	255	128	0	0	0	0	0	0	308	216	563	394	255	179
North Elmham	0	0	0	0	0	0	501	251	752	376	251	126	0	0	0	0	0	0	358	251	609	426	251	176
Old Buckenham	0	0	0	0	0	0	535	267	745	373	210	105	0	0	0	0	0	0	382	267	592	415	210	147
Saham Toney	0	0	0	0	0	0	414	207	669	335	256	128	0	0	0	0	0	0	295	207	551	386	256	179
Swanton Morley	0	0	0	0	0	0	477	238	713	356	236	118	0	0	0	0	0	0	341	238	576	403	236	165
Weeting	0	0	0	0	0	0	71	35	486	243	415	208	0	0	0	0	0	0	50	35	466	326	415	291

FROM 2055 TO 2085 (+20% in peak rainfall intensity)

Settlements	H_{min} / d_{min} ($A_{i,min}$, $PIMP_{min}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{min} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{min} / d_{max} ($A_{i,min}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{max} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	9277	81	45706	400	36429	319	13915	81	68558	400	54643	319	7215	81	43644	491	36429	410	10823	81	65466	491	54643	410
Attleborough	8459	271	14450	462	5991	192	33834	271	57799	462	23964	192	6445	271	12436	522	5991	252	25778	271	49743	522	23964	252
Dereham	4515	289	7329	469	2814	180	9030	289	14659	469	5628	180	3440	289	6254	525	2814	236	6880	289	12508	525	5628	236
Swaffham	1404	94	5355	357	3951	263	2106	94	8033	357	5927	263	1070	94	5021	439	3951	346	1605	94	7532	439	5927	346
Watton	2505	286	4102	469	1597	182	3757	286	6152	469	2395	182	1908	286	3505	526	1597	240	2863	286	5258	526	2395	240
Shipdham	1010	316	1456	455	446	139	1515	316	2184	455	669	139	721	316	1167	511	446	195	1082	316	1751	511	669	195
Great Ellingham	497	311	726	454	229	143	745	311	1089	454	343	143	355	311	584	511	229	200	532	311	876	511	343	200
Harling	84	52	456	285	372	232	126	52	683	285	558	232	60	52	432	378	372	325	90	52	647	378	558	325
Narborough	109	68	484	302	375	234	163	68	726	302	563	234	78	68	453	396	375	328	117	68	679	396	563	328
Banham	0	0	0	0	0	0	587	294	868	434	281	140	0	0	0	0	0	0	419	294	700	490	281	197
Mattishall	0	0	0	0	0	0	614	307	887	444	273	136	0	0	0	0	0	0	439	307	712	498	273	191
Necton	0	0	0	0	0	0	517	259	824	412	306	153	0	0	0	0	0	0	370	259	676	473	306	214
North Elmham	0	0	0	0	0	0	602	301	903	451	301	151	0	0	0	0	0	0	430	301	731	512	301	211
Old Buckenham	0	0	0	0	0	0	642	321	894	447	253	126	0	0	0	0	0	0	458	321	711	498	253	177
Saham Toney	0	0	0	0	0	0	496	248	803	402	307	154	0	0	0	0	0	0	354	248	662	463	307	215
Swanton Morley	0	0	0	0	0	0	572	286	855	428	283	141	0	0	0	0	0	0	409	286	692	484	283	198
Weeting	0	0	0	0	0	0	85	42	583	291	498	249	0	0	0	0	0	0	61	42	559	391	498	349

FROM 2085 TO 2155 (+30% in peak rainfall intensity)

Settlements	H_{min} / d_{min} ($A_{i,min}$, $PIMP_{min}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{min} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{min} / d_{max} ($A_{i,min}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	H_{max} / d_{max} ($A_{i,max}$, $PIMP_{max}$) Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	10050	88	49514	433	39465	345	15075	88	74272	433	59197	345	7816	88	47281	532	39465	444	11725	88	70922	532	59197	444
Attleborough	9163	293	15654	501	6490	208	36654	293	62615	501	25961	208	6982	293	13472	566	6490	273	27927	293	53888	566	25961	273
Dereham	4892	313	7940	508	3049	195	9783	313	15880	508	6097	195	3727	313	6775	569	3049	256	7454	313	13551	569	6097	256
Swaffham	1521	101	5802	387	4281	285	2281	101	8702	387	6421	285	1159	101	5439	476	4281	375	1738	101	8159	476	6421	375
Watton	2714	310	4443	508	1730	198	4070	310	6665	508	2595	198	2067	310	3797	570	1730	259	3101	310	5696	570	2595	259
Shipdham	1094	342	1577	493	483	151	1641	342	2366	493	725	151	781	342	1265	553	483	211	1172	342	1897	553	725	211
Great Ellingham	538	336	786	491	248	155	808	336	1180	491	372	155	385	336	633	553	248	217	577	336	949	553	372	217
Harling	91	57	494	308	403	252	136	57	740	308	604	252	65	57	468	409	403	352	97	57	701	409	604	352
Narborough	118	74	524	328	406	254	177	74	786	328	609	254	84	74	491	429	406	355	126	74	736	429	609	355
Banham	0	0	0	0	0	0	636	318	940	470	304	152	0	0	0	0	0	0	454	318	759	531	304	213
Mattishall	0	0	0	0	0	0	665	333	961	481	296	148	0	0	0	0	0	0	475	333	771	540	296	207
Necton	0	0	0	0	0	0	561	280	892	446	332	166	0	0	0	0	0	0	400	280	732	513	332	232
North Elmham	0	0	0	0	0	0	652	326	978	489	327	163	0	0	0	0	0	0	465	326	792	554	327	229
Old Buckenham	0	0	0	0	0	0	695	348	969	484	274	137	0	0	0	0	0	0	497	348	770	539	274	191
Saham Toney	0	0	0	0	0	0	538	269	870	435	333	166	0	0	0	0	0	0	384	269	717	502	333	233
Swanton Morley	0	0	0	0	0	0	620	310	926	463	307	153	0	0	0	0	0	0	443	310	749	524	307	215
Weeting	0	0	0	0	0	0	92	46	631	316	540	270	0	0	0	0	0	0	66	46	605	424	540	378

Table E7: Additional Runoff Volume due to Employment Development

PRESENT DAY

	Minimum						Maximum					
Settlements	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	2570	68	14106	371	11536	304	2570	68	19874	523	17304	455
Attleborough	2256	226	4253	425	1997	200	2256	226	5251	525	2996	300
Dereham	1926	241	3427	428	1501	188	1926	241	4178	522	2251	281
Swaffham	390	78	1762	352	1372	274	390	78	2448	490	2058	412
Watton	716	239	1286	429	570	190	716	239	1571	524	855	285

FROM 2055 TO 2085 (+20% in peak rainfall intensity)

	Minimum						Maximum					
Settlements	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	3084	81	16927	445	13843	364	3084	81	23849	628	20765	546
Attleborough	2707	271	5103	510	2396	240	2707	271	6301	630	3595	359
Dereham	2312	289	4113	514	1801	225	2312	289	5013	627	2701	338
Swaffham	468	94	2114	423	1646	329	468	94	2938	588	2470	494
Watton	859	286	1543	514	684	228	859	286	1885	628	1026	342

FROM 2085 TO 2155 (+30% in peak rainfall intensity)

	Minimum						Maximum					
Settlements	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)	Greenfield Runoff (m^3)	Greenfield Runoff (m^3/ha)	Developed Runoff (m^3)	Developed Runoff (m^3/ha)	Extra Runoff to store (m^3)	Long Term Storage (m^3/ha)
Thetford	3342	88	18338	483	14997	395	3342	88	25836	680	22495	592
Attleborough	2932	293	5528	553	2596	260	2932	293	6827	683	3894	389
Dereham	2504	313	4456	557	1951	244	2504	313	5431	679	2927	366
Swaffham	507	101	2291	458	1784	357	507	101	3182	636	2675	535
Watton	930	310	1672	557	741	247	930	310	2042	681	1112	371

Appendix F: Historic Flooding Records

F.1 Environment Agency data

Table F.1: Historic flood events recorded in Thetford

Date	Location	Description
9 August 1843	Thetford	Many houses flooded to 2ft deep, especially affecting in Bridge Street
20th Century	Thetford	The town centre suffered serious flooding on several occasions
26 August 1912	Thetford	Parts of the town suffered flooding but little structural damage and no loss of life
January 1915	Hockwold, 20km NW of Thetford	Little Ouse burst its bank
1939	Thetford	Memorable flooding of Thetford's rivers
1947	Thetford	Memorable flooding of Thetford's rivers
19 March 1947	Hockwold, 20km NW of Thetford	Little Ouse burst over 15m of its bank, flooding over 2500 ha of West Norfolk fenland
September 1968	Thetford	High water levels, out of bank flow and flooding, especially in Bridge Street

Source: Thetford Standard of Protection Study

Table F.2: Properties flooded during Upper River Wensum flood in October 1993

River	Location	Number of Properties Affected
Wensum	Lyng	Nine
Wensum	Lenwade	Two
Wendling Beck	Wendling	Two
Wendling Beck	Scarning	Five
Wendling Beck	Worthing	Three
Wendling Beck	Gressenhall	One

Source: Upper River Wensum Strategy Study

Table F.3: Large Raised Reservoirs

Reservoir	Location	Undertaker	Physical Status	NGR	Risk Category	Capacity (m^3)
Battles East	Near Swaffham	Knights Farms Ltd	In Operation	TF7390010400	Unknown	91,000
Bridgeham Reservoir	Near Thetford	Paul Rackham Ltd	Under Construction	TL9560086500	Unknown	230,000
Buckenham Tofts Upper	Near Thetford	Ministry of Defence	In Operation	TL8400095000	D	30,000
Caldecote Farm	Near Swaffham	Heygate Farm (Swaffham) Ltd	In Operation	TF7610004000	Unknown	90,000
Chalk Breck	Beachamwell	D.H. Sanderson and Son Ltd	Under Construction	TF7550008300	Unknown	140,000
Cley Breck North	Near Swaffham	Knights Farms Ltd	In Operation	TF7700003800	Unknown	70,000
Croxton Park Reservoir	Thetford	Croxton Park Ltd	Under Construction	TL8640086800	Unknown	320,000
Dillington Carr	Near Dereham	Gorgate Ltd	In Operation	TF9729416426	A	55,993
Fourteen Acre Field	Near Swaffham	Heygate Farm (Swaffham) Ltd	In Operation	TF8020007600	D	184,500
Hadler's Hole, Croxton Hall Farm Reservoir	Thetford	Goucher	Under Construction	TL8790086700	Unknown	140,000
Hall Farm Reservoir Illington	Thetford	Richard Johnston Ltd	Under Construction	TL9450089300	Unknown	230,000
Hamrow Farm	Near Whissonett	Stangroom Bros Ltd	In Operation	TF9110023800	Unknown	29,000
Hanger End (ID114)	Near Narborough	Narborough Farms Ltd	In Operation	TF7490810333	B	27,523
Highmoor Drove	Northwold	J.W. Spencer Farms Ltd	Under Construction	TL7680098100	Unknown	Unknown
Honey Pots (Field 6)	Near Swaffham	Knights Farms Ltd	In Operation	TF7730000600	Unknown	31,000
Kirk Hall Farm	Attleborough	Kirk Hall Farms	In Operation	TL9920095100	Unknown	81,000
Larkshall Farm Reservoir	Near Thetford	Messrs R.G. Abrey Farms	In Operation	TL9210089100	Unknown	25,000
Narford Lake	Near Kings Lynn	Fountaine	In Operation	TF7600014000	Unknown	400,000
R G Abrey Millenium Reservoir	Near Thetford	Abrey	Under Construction	TL9250089200	Unknown	460,000
South Pickenham	Near Swaffham	South Pickenham Estate Company Ltd	In Operation	TF8570003300	Unknown	312,500
Stanford Water	Near Thetford	Ministry of Defence	In Operation	TL8610095000	Unknown	85,000
Swangey Farm Reservoir	Attleborough	P F Southgate Limited	Under Construction	TM0150094300	Unknown	113,000
Top Strong Land	Near Oxborough	Oxborough Farms Ltd	In Operation	TF7580002900	D	92,000
Warren Farm Beachamwell	Near Swaffham	Heygate Farm (Swaffham) Ltd	In Operation	TF7770006300	D	92,000
Warren Gun Breck	Near Swaffham	Knights Farms Ltd	In Operation	TF7970002600	Unknown	332,000

F.2 Breckland Council data

Table F.4: Breckland Council historic flood events data

Date	Location	Type	Severity	Cause
Prior to 2005	Norwich Road, Attleborough		High – houses flooded to a depth of 3ft	Unknown
Prior to 2005	Toftwood, Dereham		Medium – localised flooding of numerous properties	Dereham Stream
Prior to 2005	Swanton Road, Dereham		Medium – localised flooding of numerous properties	Dereham Stream
Prior to 2005	Long Street, Great Ellingham	Surface water	Low	Insufficient capacity of drain running along Long Street
Prior to 2005	Swaffham		Unknown	Surface water drainage issues
After 2005	Toftwood, Dereham		Low	Blocked pipe
After 2005	Carbrooke		Low	Lack of ditch maintenance
After 2005	Great Ellingham	Surface water	Low	Highway runoff and lack of ditch maintenance
After 2005	Toftwood, Dereham		Low	Undersized pipes
After 2005	Norwich Road, Besthorpe		Low	Undersized culverts and blocked ditches
After 2005	Chantry Lane, Necton	Fluvial flooding	Medium – several properties	Undersized culvert
After 2005	Mill Lane, Attleborough		Medium – several properties	Blockage of trash screen on culvert

Table F.5: Breckland Council sandbag deliveries

Date	Street	Area
31/08/2005	Northfield Road	Swaffham
02/11/2005	Longfields	Swaffham
03/11/2005	Heidi Close	Dereham
04/11/2005	Longfields	Swaffham
10/11/2005	Longfields	Swaffham
18/11/2005	Old Becclesgate	Dereham
19/06/2006	Old Becclesgate	Dereham
27/06/2006	Griston Road	Caston
24/08/2006	Byron Walk	Thetford
24/08/2006	Melville Road	Croxton
24/08/2006	Stanford Road	Thetford
24/08/2006	Elgin Way	Thetford
24/08/2006	St Johns Way	Thetford
24/08/2006	Earls Street	Thetford
24/08/2006	St Marys Crescent	Thetford
24/08/2006	St Marys Crescent	Thetford
10/10/2006	Norwich Road	Dereham
07/12/2006	Market Street	Shipdham
10/01/2007	The Street	Rocklands
10/01/2007	The Street	Rocklands
10/01/2007	Thorpe Farm Cottages	Shadwell
10/01/2007	Bunwell Road	Besthorpe
10/01/2007	Silver Street	Besthorpe
10/01/2007	-	Caston
10/01/2007	Long Street	Great Ellingham
10/01/2007	Kenninghall Road	Harling
10/01/2007	Cake Street	Old Buckenham
11/01/2007	Manor Close	Lyng
11/01/2007	Market Street	Shipdham
12/01/2007	Cake Street	Old Buckenham
17/01/2007	-	Cranworth
19/06/2007	Church Road	Worthing
21/06/2007	Fairfields	Thetford
22/06/2007	Old Becclesgate	Dereham
25/06/2007	Fakenham Road	Horningtoft
25/06/2007	Hammond Place	Lyng
25/06/2007	Fakenham Road	Horningtoft
25/06/2007	Station Lane	Thuxton
25/06/2007	Brandon Road	Swaffham
25/06/2007	Post Office Lane	Reymerston
25/06/2007	New Road	Whissonsett

25/06/2007	-	Twyford
25/06/2007	Brackenwoods	Necton
26/06/2007	Saham Road	Ovington
26/06/2007	Saham Road	Ovington
26/06/2007	Saham Road	Ovington
26/06/2007	The Street	Caston
27/06/2007	Billingford Road	North Elmham
27/06/2007	Manor Close	Hockering
27/06/2007	Port Row	Lyng
27/06/2007	Port Row	Lyng
28/06/2007	Port Row	Lyng
28/06/2007	The Street	Bridgham
28/06/2007	Port Row	Lyng
28/06/2007	Shipdham Road	Dereham
28/06/2007	Hale Road	Necton
28/06/2007	Nelson Court	Watton
28/06/2007	Saham Road	Ovington
28/06/2007	Old Bridge	Gressenhall
28/06/2007	Dereham Road	Litcham
29/06/2007	Saham Road	Ovington
29/06/2007	School Plain	Scarning
29/06/2007	The Street	Foxley
02/07/2007	Ash Close	Swaffham
02/07/2007	Sporle Road	Swaffham
02/07/2007	The Paddocks	Swaffham
05/07/2007	Brackenwoods	Necton
05/07/2007	Market Street	Shipdham
05/07/2007	Market Street	Shipdham
05/07/2007	Beatrice Avenue	Dereham
19/07/2007	Blenheim Crescent	Tittleshall
26/07/2007	Charles Close	Dereham
03/07/2007	Dodma Road	Weasenham St P

F.3 Anglian Water data

Table F.6: Anglian Water Sewer Flooding Data

Date	Location Town	Location Detail	Reporting Category	Register Frequency
10/04/1998	Bawdeswell	Reepham Rd	Internal	1 in 10
	Dereham	Boyd Ave	External	1 in 10
	Dereham	Hillcrest	External	1 in 10
	Dereham	Norwich Road	External	2 in 10
	Dereham	Norwich Road	External	1 in 20
	Dereham	Rash's Grn	External	1 in 20
	Dereham	Shipdham Rd	External	1 in 20
	Dereham	South Green	External	1 in 10
	Dereham	South Green	External	1 in 20
	Dereham	Swanton Grove	External	1 in 20
	Dereham	Swanton Grove	External	1 in 20
	Dereham	Swanton Road	External	1 in 20
	Dereham	Swanton Road	External	1 in 20
	Dereham	Swanton Road	External	1 in 20
	Dereham	Swanton Road	External	1 in 20
	Dereham	Wellington Road	External	1 in 20
	Dereham	Larner's Drift	Internal	2 in 10
	Saham Toney	Bell Lane	External	1 in 10
	Shipdham	Chapel Street	Internal	2 in 10
31/08/2006	Thetford	Bridges Walk	External	1 in 20
	Thetford	Bridges Walk	Internal	1 in 20
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10
	Thetford	Fairfields	Internal	2 in 10

Date	Location Town	Location Detail	Reporting Category	Register Frequency
24/08/2006 and 03/03/2007	Watton	Norwich Road	External	2 in 10
06/10/2006	Watton	Saham Road	External	1 in 20
23/08/2006	Watton	Saham Road	External	1 in 20
17/08/2006	Watton	Swaffham Road	External	1 in 20
	Watton	Norwich Road	Internal	2 in 10
	Watton	Norwich Road	Internal	1 in 10
	Watton	Norwich Road	Internal	2 in 10
	Watton	Norwich Road	Internal	2 in 10
	Watton	Wissey Grove	External	1 in 10
	Watton	Wissey Grove	External	1 in 10
	Whissonsett	North View	External	1 in 20

Note:

- Each line corresponds to one property which has been flooded. For data protection reasons, Anglian Water did not provide the exact property identifications.
- Date – in the DG5 Register only the earliest and most recent event dates are recorded. For rate of recurrence see Frequency. No date does not infer that no flood event has occured.
- Internal – flooding occurred within the property
- External – flooding occurred outside the property

F.4 Highways Agency data

There are two trunk roads in the Breckland District under the authority of the Highways Agency (the A11 and the A47). Data of historic flood events on these roads since 2002 is presented in Table F.7:

Table F.7: Highways Agency historic flood events data

Date Of Call	Location	Description
15/08/2002	A47 Between Honningham & Hockering	Flooding in residents' gardens
06/11/2002	A47 slip road to Swaffham	Flood on road
29/12/2002	A47 Dereham by-pass	Serious flooding on road
14/03/2003	A47 Dereham, between Middlemitch + Moorgate roads	Flooding on underpass
30/07/2003	A47 Dereham just after B11110 Junction	Flooding across main carriageway, risk of aquaplaning
20/12/2003	A47 Wending junction near Beeston	Flood in carriageway
06/02/2004	A11 Attleborough bypass	Flood in lane 2
26/04/2004	A11 Snetterton	Flooding on underpass
28/04/2004	A11 Stone Cross, Roudham Heath	Flooding on underpass
04/05/2004	A11 Stone Cross	Area flooding due to pump not working
08/07/2004	A47 Hockering	Flooding reported as "torrent" across road eastbound
09/07/2004	A47 Dereham	Blocked gully near pond causing flood
12/08/2004	A47 at Necton	Flooding quite bad eastbound
23/08/2004	A11 Stone Cross	Bad flooding
27/08/2004	A11 Quidenham	Flood on road
14/10/2004	A11 Thetford Bypass	Flood on road
07/07/2005	A47 between Scarling & Little Fransham	Blocked gully causing possible flooding westbound
03/08/2006	A11 Stone Cross, Roudham Heath	Flooding road – pump needs assessing
24/08/2006	A11 Thetford between A1075 R/Bt and Croxton interchange	Flooded central reservation and north side – gully heads need freeing up
24/08/2006	A11 Thetford, south of Sainsburys roundabout	Lay-by entrance flooded
20/09/2006	A11 S/B Snetterton. Stone cross	Flooding on underpass
01/10/2006	A11 Stone Cross, Roudham Heath	Flood warning signs requested
02/10/2006	A11 Stone Cross, Roudham Heath	High level flooding
10/01/2007	A11 Besthorpe	Flooding in both lanes
21/01/2007	A11 1st Turn for Thetford	Flooding under road, due to a fault with the pumping station
08/05/2007	A11 Thetford just south of BP garages	Flood on road
25/06/2007	A47 approx 1 mile after Little Fransham	Reports of flood water approx 2ft deep & 100 yards in length
25/06/2007	A47 Mattishall turning	Localised flooding

F.5 Online Newspaper "Lynn News"

Floods bring hidden dangers

Published Date: 12 September 2002

KEY PLAYERS are being brought together to try to find a solution to major flooding problems that occur in Swaffham after sudden downpours. Swaffham Town Council is inviting Anglian Water, the EA, Norfolk County Council highways and Breckland Council's environmental health department to a meeting at the town hall on Wednesday, October 3.

And South West Norfolk MP Gillian Shephard, who contacted the EA about the town's surface water problems, also hopes to be there. She said: "I have always found the best solution to a difficult problem is to get all the interested parties round the table. "If you do this it means nobody can shelter behind anyone else." I'm sure there's a common aim to solve this problem and that those responsible need to know how local people feel!"

Town Mayor Mr Ben Emmerson told the Lynn News that he had been complaining about flooding in the Sporle Road, New Sporle Road and West Acre Road areas after heavy rain for the past 30 years. "We get raw sewage coming up and that creates a health problem because in hot weather there are children paddling in the floodwater," he pointed out.

Seventy-six-year-old Harold Clarke, a Swaffham resident all his life, is among those who have written to the town council calling for action to stop the flooding. He lives at 19 Sporle Road, close to one of the worst problem spots, and after a thunderstorm on July 30 had floodwater covering half his front garden. Mr Clarke said if the drain covers remained clear they could cope with heavy rain but flooding occurred when they became blocked by rubbish and debris. Overflow from Northwell Pool and water running down Sporle Road and off three nearby housing estates added to the flooding and the pressure lifted heavy manhole covers off sewers, he said. "Effluent gets into the water and children play in it and splash it over each other. "It only needs something to get in an eye, nose, mouth or ear to cause horrendous disease," he added. His neighbour Isabel Caseiro said that it was hard to stop her two-year-old son Kevin from playing in the water because he saw other youngsters were splashing about in it and thought it was like being at the seaside.

Mrs Pat Moore said water always laid in the road near her home at 11 Longfields after heavy downpours, and cars passing through it sent waves across her garden. "It's alright for ducks but not for us," she said. Widow Gwen Mortimer, of 4 New Sporle Road, has even resorted to keeping a heavy plant pot on a drain cover in her front garden to stop it coming off after deluges. "Last time it was like a river on the road outside, with sewage and everything in it," she said.

Storm brings havoc

Published Date: 20 June 2003

THUNDER, lightning and heavy rain caused havoc across West Norfolk on Tuesday evening with power cuts, flash flooding and a 1,000-year-old church tower struck by lightning.

A spokesman for electricity provider 24Seven said West Norfolk was the most seriously affected area on its East Anglian power grid and a weather expert said some towns and villages received half their average monthly rainfall in the space of an hour. RAF Marham's weather station recorded 22.6mm, just under an inch, of rainfall in only an hour between 7pm and 8pm – average monthly rainfall figures are 50mm. More than 3,000 households were left without power when electricity supplies were struck by lightning and homes in West Winch, Downham and Gaywood were affected by flash flooding. Norfolk fire service reported an extremely busy evening pumping water out of homes and Lynn police responded to calls in Castle Rising, West Winch, Weeting and Blackborough End between 7pm and 9pm because of flooded roads.

The most spectacular damage was done when a bolt of lightning hit the 90ft-high tower of Grimston's St Botolph's Church blasting half a tonne of masonry and stonework onto the lower 6ft-high turret roof and scattering it for 50 yards on the ground. Churchwarden Roger Haywood said the explosion, which he described as a "huge bang, red flash and clouds of dust", happened at about 6.30pm and caused about £20,000 of damage to the church, which dates back to about 1200AD. It also attracted about 100 onlookers, among them young scouts and school governors who were attending meetings at nearby Grimston Junior School. Part of the graveyard has now been fenced off and Mr Haywood said they would be unable to ring the church bells until the damage was fixed.

West Winch couple Paul and Carol Rose, of Southfield Drive, said they deeply appreciated help from villagers when their house was flooded. Mr Rose said: "Children were slowing down traffic to prevent further flooding from inconsiderate drivers, people came with buckets and waded in ten inches of water to bail us out."

The high voltage network serving the Woottons was hit by lightning leaving 2,800 in North and South Wootton without power from about 6.30pm. Service was restored between 7pm and 8.45pm. Lightning also caused two faults on the network at Tottenhill at about 7.30pm interrupting power supplies to 450 customers. Service was restored between 1.45am and 7.30am on Wednesday with seven customers waiting until noon.

Weatherquest forecaster Mr Phil Garner said the storm moved into the area from Wisbech at about 5.30pm and moved out through Swaffham and the Creakes by 8pm. He said it was a typical summer storm caused by hot air, built up over the previous few days, from the south meeting cold air moving in from the west. Thanks for flood help...see Page 14.

Flooding hell

Published Date: 29 June 2007

Polluted floodwater lies around a house and garage in Chantry Lane, Necton, on Monday evening following a downpour that day.

Elderly people living in low-lying parts of Necton feared their homes were about to be flooded with sewage-polluted water as torrential rain hit the village this week. Firefighters were called in on Monday evening to pump away floodwater threatening bungalows in Chantry Lane, Chantry Court and Mill Street – in scenes similar to the devastating floods in Yorkshire shown on TV news reports.

Necton Parish Council chairman Frank Woodward's phone was inundated with calls for help from OAPs that day." It rained like hell in the morning and I noticed the drains were blocked in Chantry Lane," he said. The parish council tried to get Anglian Water to send a team to find out why water was lying up to two feet deep in Mill Street and Chantry Lane, but without success. Calls were also made to Norfolk County Council, which recently had someone inspect a culvert in Chantry Lane, and to Breckland Council, which provided sandbags for those in immediate danger but not enough, he said. Mr Woodward stressed: "In these situations, the emergency services are not adequate. "When you try to talk to someone you find the office is shut. "People panic because they want something done straight away; you can't just have emergencies in office hours." The pensioners were worried and some were walking around in pyjamas because they were getting sewage in the house."

Eighty-six-year-olds Elsie and Albert Kellingray watched anxiously as water swamped their garden in Chantry Lane up to the doorstep, reviving frightening memories of a similar experience in 1982 when they had six inches of floodwater in their bungalow. "The rain was so torrential – I have never seen anything like it," Mrs Kellingray said. "The sewage was bubbling up from a big drain near our bungalows." A neighbour called the fire service about 6pm and the firefighters laid two pipes to take the surplus water to a dyke. Bernard Bell (69), who lived in Chantry Lane from 1967 to 1997, said during exceptional and prolonged storms the culvert could not cope with the excess amount of surface water from the new housing estates, and flooding resulted. On Monday, raw sewage got into the floodwater where a manhole cover had lifted. "If the fire brigade had not pumped out from that low place I'm sure some of those bungalows would have been flooded out again," he said.

An Anglian Water spokesman said there were no pump failures or blockages at its Necton pumping station. "It was just the sheer quantity of the downpour and that's not something our system is designed to take in such a short time," she said. "We seem to be seeing this more across the country – there's a whole rash of issues that need looking at, including highway gulleys, maintenance of historical drainage dykes and ditches, the amount of tarmacadam used and the run-off from brickweave drives." A county council spokesman said: ""We fully appreciate that this is a serious concern and are working with Breckland Council to address the flooding issues in the village as quickly as we can." We think that there is a blockage in the culvert and need to find out first what is causing it. We are therefore arranging to have it inspected by CCTV."

Appendix G: Data Sources for Fluvial Modelling and Mapping

G.1 Terrain Data

Figure G.1 shows the coverage of LiDAR data in Breckland. SAR data covers the entire district.

G.2 Hydrological Data

Table G.1: River Gauging Stations in Breckland

Gauge Name and No.	River	NGR	Dates of Record	Indication of Data Quality (from HiFlows Project)
Abbey Heath (33034)	Little Ouse	TL85108440	1969 - 2000	Good, high stage records are mostly in bank, within reliable part of rating.
County Bridge Euston (33011)	Little Ouse	TL89208020	1960 - 2001	Good, full rating of site produced including out of bank flow estimation
Rectory Bridge (33013)	Sapiston	TL89557905	1960 - 2001	Good up to flows of $8m^3/s$
Melford (33019)	Thet	TL88008300	1963 - 2002	Good, rating included for out of bank flow shows good fit to gauging.
Bridgham (33044)	Thet	TL95708550	1968 - 2002	Poor at high flows, out of bank flow rating not found, and there is limited gauging at low flow.
Redbridge (33046)	Thet	TL99609230	1968 -2002	Poor at high flows, no out of bank flow rating has been collected
Quidenham (33045)	Whittle	TM02708780	1969 - 2002	Good, quality reduces at high flows
Stonebridge (33048)	Larling Brook	TL92759070	1970 - 2002	Good up to 0.358 m3/s, no out of bank rating collected
Northwold Total (33006)	Wissey	TL77109650	1956 - 1979, 1985 - 2002	Poor, an out of bank rating has been developed for the main weir however this does not fit the gaugings above a stage of 0.3m on the main weir
Buckenham Tofts (33049)	Stanford Water	TL83909500	1967 - 1973	Poor at high flows, no high flow rating collected
Marham (33007)	Nar	TF72351200	1970 - 2002	Good for data after 1982
Costessey Park (34005)	Tud	TG17001130	1961 - 2002	Good, including high flows
Colney (34001)	Yare	TG18200820	1958 - 2002	Poor, full rating review needed. No suitable rating found
Costessey Mill (34004)	Wensum	TG17701280	1960 - 1987, 1997 - 1999	Not recommended for high flows
Swanton Morley (34014)	Wensum	TG02001840	1969 - 1999	Not included in the Hi-flows project
Fakenham (34011)	Wensum	TF91902940	1967 - 2002	Poor, the gate operations make the use of this site very limited.

Figure G.2 shows the location of river gauging stations in Breckland.

Figure G.1: Coverage of LiDAR Data

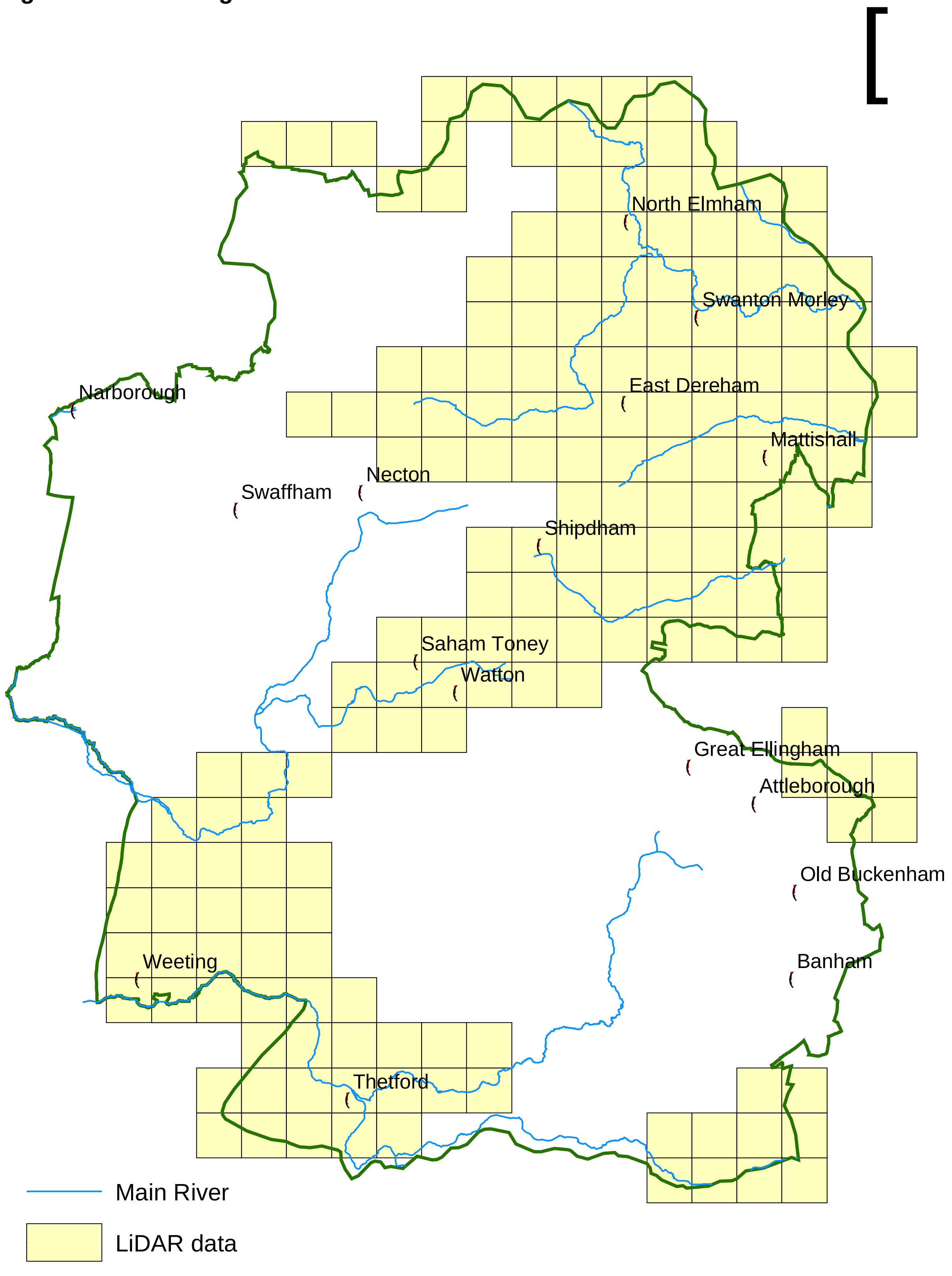
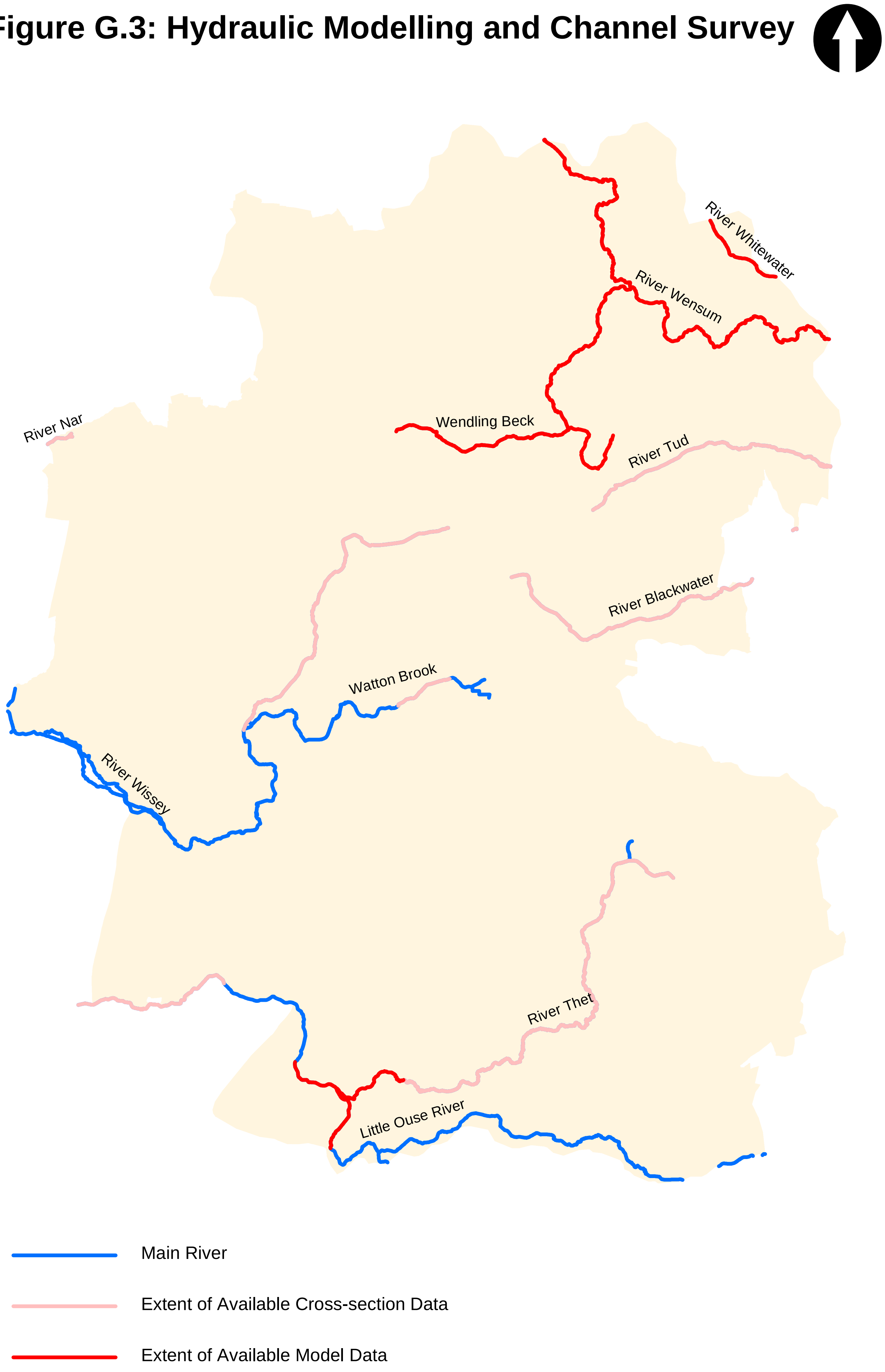


Figure G.2: River Gauging Stations

Figure G.3: Hydraulic Modelling and Channel Survey



G.3 Hydraulic Modelling Data

Table G.2: Existing Hydraulic Models in Breckland

Watercourse	Reach covered	Report Date	Report Authors	Client	Software
River Thet and River Little Ouse	Thetford	2006	Halcrow	EA	iSIS
Upper Yare	From Shipdham to western outskirts of Norwich	2005	Babtie, Brown and Root	EA	iSIS
River Tud	From Dereham to confluence with the River Yare	2005	Jeremy Bens Associates	EA	iSIS
River Thet	East Harling	2005	Mott MacDonald	Breckland Council	iSIS
Watton brook	Watton	2005	Mott MacDonald	Breckland Council	iSIS
River Wissey	Necton	2005	Mott MacDonald	Breckland Council	iSIS
River Wensum	River Tat confluence to Costessey Mill, tributaries Wendling Beck and Whitewater.	2003	Babtie, Brown and Root	EA	iSIS
Dereham Stream	Norwich Rd, Dereham to Wendling Brook confluence.	1991	Mott MacDonald	King's Lynn Consortium	HYDRO-1D

These models are the latest versions available for these river reaches.

Table G.3: Channel Cross Section Survey in Breckland

River	Upstream Limit	Downstream Limit	Survey Date	Format	Cross Section Spacing
Whitewater	Main River Limit, Nr Lizard Farm	Blackwater Lane	May 1994	Digital	250m
Tud	Main River Limit, Spurn Farm, Dereham	A47, Honingham	Oct – Nov 1993	Digital	250m
Blackwater (Yare)	Shipdham Road Bridge	Hardingham Gravel Pits	Sept – Oct 1993	Digital	250m
Wensum	Great Ryburgh	Weston Hall	July – Oct 1993	Digital	250m
Wendling Beck	Main River Limit	Conf. with Wensum	May 1993	Digital	250m
Little Ouse	Santon Downham	Brandon	Unknown	Digital	200m
Little Ouse	South Thetford	Abbey Heath Weir	Nov 1992	Digital	150m
Thet	Bridgham	Confluence with Little Ouse	Dec 1993	Digital	200m
Thet	Bridgham	Bridgham	Dec 2000	Digital	100m
Thet	Harling	Bridgham	Dec1993	Digital	200m
Thet	Swangey Fen	Harling	March 1994	Digital	200m
Nar	Main River Limit	South Lynn	March 1993	Digital	200m
Wissey	Main River Limit	Confluence with Watton Brook	Feb 1992	Digital	200m
Watton Brook	Central Watton	Watton	Jan 1991	Hardcopy	200m

Figure E.3 shows the location of the cross section survey and existing hydraulic modelling in Breckland, prior to any modelling completed for the purpose of this study.

Appendix H: Outfalls from Sewage Treatment Works

Data was received from Anglian Water giving details of discharge consents within Breckland. This was rationalised in order to show sewage treatment work outfalls. There are 96 such outfalls in Breckland District; these are shown in Figure H.1 and listed in Table H.6. It should be noted that of the 96 outfalls, only 42 have a consented value for daily "dry weather" discharge and only 15 have a consented value for daily maximum discharge.

The outfalls that could potentially be utilised by the possible development sites are documented below. The selection of potential outfalls has been based on proximity to the possible development sites. The potential outfalls have then been ranked based on a broad assessment of the likely impact of the increased discharges on the receiving watercourse. The full impact of the discharge on the receiving watercourse needs to be considered in detail at the planning stage to take account of the nature and size of specific proposals for development.

H.1 Attleborough

There are four potential sewage works outfalls near Attleborough, one of which discharges to a tributary of the River Thet on the District border (ID 60). The other sewage works discharge into IDB controlled tributaries of the Thet, all of which are shown in the SFRA to flood during a 1% flood event. Of the four sewage treatment works, none have a consented daily maximum discharge, and only Attleborough STW has a consented daily "dry weather" discharge. Attleborough STW has been given the highest rank solely on the fact that it will be discharging further downstream into the Thet system than the three alternatives.

As all the potential receiving watercourses are shown to be prone to flooding during a 1% flood event, detailed assessments would be required before any additional discharges are allowed to them. The detailed assessments should take into account the specific nature and size of proposed developments.

Table H.1: Outfalls from Sewage Works around Attleborough

ID	Rank	EA Reference	Name	Receiving Watercourse	Consented dry weather discharge (m^3/day)
44	1	AW1NF1059	Attleborough STW	Tributary River Thet	2500
54	2	AW1NF1PA	Besthorpe (Bunwell) STW	Tributary River Thet	-
60	2	AW1NF2P	Besthorpe (Norwich) STW	Tributary River Thet	-
01	2	AECLF23	Attleborough Poplar Road STW	Tributary River Thet	-

H.2 Dereham

The only sewage works outfall in Dereham is Dereham STW which discharges into the Main River of Wendling Beck. The STW has a consented daily “dry weather” discharge of 3769 cubic metres. The SFRA has shown that the floodplain downstream of the STW is assessed to flood in a 1% event but does not currently pose a significant flood risk to residential areas.

To assess the full impact of additional discharge downstream of the STW a detailed assessment would be required taking into account the specific nature and size of the proposed development.

Table H.2: Outfalls from Sewage Works around Dereham

ID	Rank	EA Reference	Name	Receiving Watercourse	Consented dry weather discharge (m^3/day)
42	1	AEENF527	Dereham STW	Wendling Beck	3769

H.3 Swaffham

The only sewage works close to Swaffham is Swaffham STW which discharges into the River Wissey to the south of Swaffham. The STW is located approximately 3km from the river and has a consented daily “dry weather” discharge of 1000 m^3. The SFRA assesses that the watercourse would flood in a 1% event, but does not pose a significant flood risk to residential areas immediately downstream of the discharge location.

To assess the full impact of additional discharge downstream of the STW a detailed assessment would be required, taking into account the specific nature and size of the proposed development.

Table H.3: Outfalls from Sewage Works around Swaffham

ID	Rank	EA Reference	Name	Receiving Watercourse	Consented dry weather discharge (m^3/day)
45	1	AW1NF1077	Swaffham STW	River Wissey	1000

H.4 Thetford

There are two potential outfalls close to the town of Thetford. Both of these discharge into the River Little Ouse downstream of Thetford; neither has a consented discharge volume. The two STW are within 700m of each other. Thetford STW has been given the highest rank as it is the larger of the two and is downstream of a major structure across the river. The land downstream of this outfall is largely undeveloped. The maps from the SFRA show that this watercourse will potentially flood in a 1% flood event, with residential areas in Brandon shown to be at flood risk.

To assess the full impact of additional discharge downstream of the STW a detailed assessment would be required, taking into account the specific nature and size of the proposed development.

Table H.4: Outfalls from Sewage Works around Thetford

ID	Rank	EA Reference	Name	Receiving Watercourse	Consented Discharge (m^3/day)
57	1	AW1NF260	Thetford STW	River Little Ouse	-
12	2	AECNF11036	Brandon Rd STW	River Little Ouse	-

H.5 Watton

There are four potential sewage works outflows near Watton. These all eventually discharge into Watton Brook downstream of the town; none of them has a consented discharge volume. Of these outfalls only Watton STW discharges into a Main River. As all outfalls discharge into the same system, Watton STW has been given the highest rank since additional discharge is assessed to have the smallest impact. Information from the SFRA maps shows that this watercourse will potentially flood in a 1% flood event, although no residential areas are currently shown to be at flood risk.

To assess the full impact of additional discharge downstream of the STW a detailed assessment would be required, taking into account the specific nature and size of the proposed development.

Table H.5: Outfalls from Sewage Works around Watton

ID	Rank	EA Reference	Name	Receiving Watercourse	Consented Discharge (m^3/day)
76	1	AW1NF958	Watton STW	Watton Brook	-
19	2	AECNF2140	Bell Lane	Trib of Watton Brook	-
47	2	AW1NF11PA	Ovington STW	Trib of Watton Brook	-
96	2	PRCNF14325	Ockleigh	Watton Wick Brook	-

Table H.6: Outfalls from Anglian Water Sewage Works with Discharge Contents

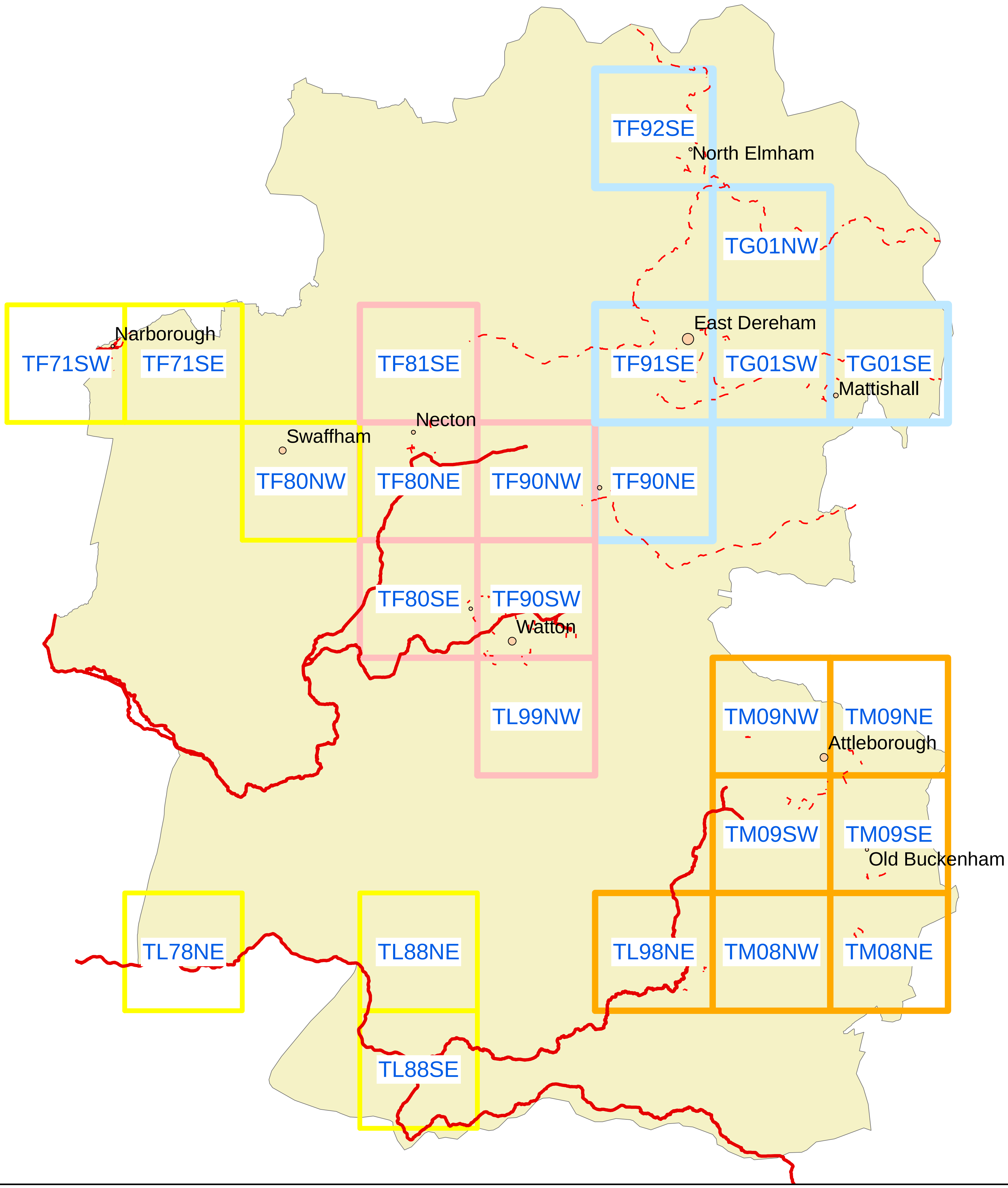
ID	EA Number	Name	Receiving Watercourse	NGR	Dry weather (m^3)	Max daily (m^3)
1	AECLF23	Attleborough Poplar Rd STW		TM0423893497	0	0
2	AECLF26	Croxton Breckwick H STW	Soakaway	TL8715087150	0	0
3	AECLF27	Croxton(Church Av) STW	Soakaway	TL8745086750	0	0
4	AECLF28	Griston(Carbrooke Rd	Soakaway	TL9435099550	0	0
5	AECLF31	Scoulton STW	Soakaway	TF9780000700	0	0
6	AECLF33A	Stow Bedon Station STW	Soakaway	TL9447096410	0	0
7	AECNF10262	Castle Acre STW	Trib R Nar &/or land	TF8239015100	0	0
8	AECNF10452	Caston (Coronation Rd)	unnamed trib River Thet	TL9616097280	0	14
9	AECNF1062	East Harling STW	River Whittle NT	TM0104088040	470	0
10	AECNF11013	Hilborough STW	River Wissey	TL8264099800	0	0
11	AECNF11028	Great Dunham (North) STW	unnamed drain River N	TF8720015080	1	0
12	AECNF11036	Brandon Rd Tps Thetford	R Little Ouse	TL8600083250	0	0
13	AECNF1111	Kenninghall(School) STW	River Whittle NT	TM0380085800	22	0
14	AECNF11621	Carbrooke Church Rd STW	Watton Brook	TF9491002050	70	182
15	AECNF1259	Beeston STW	Trib River Nar	TF9182015960	40	0
16	AECNF15	Rocklands(Rectory) STW		TL9900096040	0	0
17	AECNF2080	Mundford STW	Tributary R Wissey NT	TL7900094400	0	0
18	AECNF2113	Attleborough Road Old Buckenham		TM0625091770	0	0
19	AECNF2140	Bell Lane Saham Toney		TF9061001890	0	0
20	AECNF2695	Wash Lane Banham		TM0621087640	0	0
21	AECNF45	Snetterton STW	River Thet NT	TL9959092270	0	0
22	AECNF8	Kenninghall(Banham) STW	River Whittle NT	TM0380086400	0	0
23	AEELF12293	Brisley Hsw	Groundwater	TF9502021720	4	27
24	AEELF12294	Elsing	Groundwater	TG0531016920	3	19
25	AEELF12295	Garvestone	Groundwater	TG0212007520	8	57
26	AEELF12297	Heath Road Hsw	Groundwater	TG0567017080	5	38
27	AEENF102	Hardingham STW	R Blackwater R Yare NT	TG0428003920	0	0
28	AEENF10356	South Lopham (Church Rd)	Unknown Trib. R Waveney NT	TM0416081660	0	0
29	AEENF10509	Gateley STW	Trib R Wensum NT	TF9617024530	5	6
30	AEENF108	Cranworth STW	Trib River Yare NT	TF9800004700	0	0
31	AEENF112	Little Fransham(Gc) STW	Trib of Wendling Beck	TF9010012730	0	0
32	AEENF119B	Weasenham St.Peter STW	Trib River Wensum NT	TF8515022390	0	0
33	AEENF12055	Foulsham STW	Foulsham Beck R Wensum	TG0246024350	299	0
34	AEENF121	Whinburgh STW	Tributary R Yare NT	TG0090008900	0	0
35	AEENF12129	Horningtoft STW	tributary River Wensum	TF9286023990	4	10
36	AEENF12148	Fprge Cottage CSO	tributary River Tud	TG0472011220	0	0
37	AEENF12417	East Bilney STW	R Blackwater	TF9478019720	22	54
38	AEENF1310	Shipdham STW	R Blackwater	TF9577905939	430	0

ID	EA Number	Name	Receiving Watercourse	NGR	Dry weather (m^3)	Max daily (m^3)
39	AEENF2076	Mattishall STW	River Tud NT	TG0261412051	720	0
40	AEENF245	North Lopham(Kh) STW	Trib River Waveney NT	TM0320083300	0	0
41	AEENF321	Billingford STW	Trib R Wensum NT	TG0175020230	0	0
42	AEENF527	Dereham STW	Wendling Beck R Wensum NT	TF9763313605	3769	0
43	ASCLF11484	Rougham Council Houses STW	To Land	TF8310020620	6	40
44	AW1NF1059	Attleborough STW	Trib River Thet NT	TM0272395104	2500	0
45	AW1NF1077	Swaffham STW	River Wissey NT	TF8335306592	1000	0
46	AW1NF107A	Cockley Cley STW	R Gadder R Wissey NT	TF7957004210	23	0
47	AW1NF11PA	Ovington STW	Trib of Watton Brook	TF9248002300	0	0
48	AW1NF1340	Church End Banham		TM0624088340	0	0
49	AW1NF1457	Little Ellingham STW	Trib River Thet NT	TM0040099100	13	0
50	AW1NF1465	Rocklands Wayland Rd STW		TL9930097300	0	0
51	AW1NF14PA	Thompson STW	Trib River Wissey NT	TL9204096390	0	0
52	AW1NF176	Bradenham STW	River Wissey NT.	TF9110008700	80	0
53	AW1NF18PA	Great Ellingham STW	Trib of Portwood Brook	TM0230097800	110	0
54	AW1NF1PA	Besthorpe(Bunwell) STW	Trib River Thet NT	TM0710095670	0	0
55	AW1NF214	Gooderstone STW	R Gadder R Wissey NT	TF7530002000	112	0
56	AW1NF2506	Hockham STW	Hockham Hall Stream R Thet	TL9518091590	0	0
57	AW1NF260	Thetford STW	Little Ouse	TL8560783716	0	0
58	AW1NF2678	68 The Street	Trib R Little Ouse N	TM0060081500	7	0
59	AW1NF2770	Garboldisham-Hopton Rd	Trib River Little Ouse	TM0027080980	12	0
60	AW1NF2P	Besthorpe(Norwich) STW	Tributary R Thet NT	TM0720097500	0	0
61	AW1NF443A	Merton STW	Trib of Sturston Carr R Wissey	TL9059098560	0	0
62	AW1NF512	STW - Quidenham	Tributary River Thet NT	TM0210089800	10	0
63	AW1NF561A	Two Mile Bottom STW	River Little Ouse NT	TL8530086400	0	0
64	AW1NF61	Barnham STW	Trib R Little Ouse	TL8726279301	136	0
65	AW1NF623A	Old Buckenham STW	Buckenham Stream River Thet N	TM0619290548	0	0
66	AW1NF657A	Little Dunham STW	Trib of R Wissey River Gre	TF8690012500	0	0
67	AW1NF659A	Foulden STW	Foulden Stream River Wissey N	TL7560098800	75	0
68	AW1NF675	Weeting STW	Little Ouse	TL7680087700	0	0
69	AW1NF70A	Great Cressingham STW	Trib River Wissey NT	TF8520002300	0	0
70	AW1NF744A	House at corner Newtown Rd/Main St	Tributary River Nar NT	TF8720014400	0	0
71	AW1NF7P	Gasthorpe STW	Trib R Little Ouse N	TL9768080830	0	0
72	AW1NF832A	Necton (Sporle) STW	Trib R Wissey NT	TF8603509100	0	0
73	AW1NF939A	Brandon STW	River Little Ouse	TL7762086290	0	0
74	AW1NF941	Blo' Norton STW	Trib of Little Ouse	TM0140079400	13	0
75	AW1NF943	Bridgham Biox STW	Trib River Thet NT	TL9610085900	5	0

ID	EA Number	Name	Receiving Watercourse	NGR	Dry weather (m^3)	Max daily (m^3)
76	AW1NF958	Watton STW	Watton Brook	TF8866800123	0	0
77	AW4NF1046X	Swanton Morley Airfield STW	River Wensum NT	TG0150318531	227	0
78	AW4NF199X	North Elmham STW	River Wensum NT	TF9984121291	262	0
79	AW4NF290X	Hockering STW	River Tud NT	TG0780012700	150	0
80	AW4NF314BX	Sparham (Wells Close)	Trib R Wensum NT	TG0710019700	0	0
81	AW4NF325X	Wendling STW	Trib River Wensum	TF9356013620	5	14
82	AW4NF330X	Fransham Sewage Disposal No 1 Site		TF9010012000	0	0
83	AW4NF396X	Fersfield		TM0600083000	0	0
84	AW4NF405BX	Foxley(Laurence Rd) STW	Trib of R Wensum NT	TG0380021800	8	0
85	AW4NF405X	Weasenham All Saints STW	Trib River Wensum NT	TF8490022100	8	0
86	AW4NF418X	East Tuddenham		TG0700011000	0	0
87	AW4NF624X	Bylaugh STW	River Wensum NT	TG0371118324	690	4595
88	AW4NF636X	Tasburgh & Hapton		TM1000090000	0	0
89	AW4NF673X	Stanfield STW	Trib River Wensum NT	TF9360020800	3	0
90	AW4NF673X1	Foxley(Norwich Rd) STW	River Wensum NT	TG0360021500	0	0
91	AW4NF68X	Yaxham Council Houses		TG0000001000	0	0
92	AW4NF790	Litcham STW	Narrowgate Stream	TF8914417228	255	1200
93	AWCNF11341	Narborough STW Feps	unnamed watercourse	TF7405012620	0	0
94	AWCNF11369	Riddlesworth STW	Trib River Little Ouse	TL9552080990	2	7
95	PR1LF2236	Church Road	Internal Drain R Thet	TL9430098800	6	0
96	PRCNF14325	Mr & Mrs J Robertson	Watton Wick Brook	TL9134099810	0	5

Note: Where the dry weather or maximum daily discharge is given as zero, this indicates that no value has been agreed for the consent.

Appendix I: Key Plan for O.S. Map Tiles



Project Title

Breckland DC Strategic Flood Risk Assessment

MapTitle

Key Plan for OS Tiles

Figure I.1

Breckland

Mott MacDonald

Drawing Date 09/03/2005 Rev 1

Drawing ID:\238050 Breckland SFRA\Report\Updated Figures\Key Plan for OS Tiles.mxd