Tonbridge and Malling Borough Council
Gibson Drive
Kings Hill
West Malling
Kent
ME19 4LZ

Strategic Flood Risk Assessment

Tonbridge and Malling Borough Council

Stage 2 Report

August 2006

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Glossary

AOD	Above Ordnance Datum
DSM	Digital Surface Model
DTM	Digital Terrain Model
EA	Environment Agency
EFO	Extreme Flood Outline
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FSR	Flood Studies Report
FW	Foul Water
GIS	Geographical Information System
IFM	Indicative Flood Map
IFSAR	Interferometric Synthetic Aperture Radar
LAMP	Local Asset Management Plan
LiDAR	Light Detection and Ranging
NFCDD	National Flood and Coastal Defence Database
OS	Ordnance Survey
PPG25	Planning Policy Guidance Note 25
PPS25	Planning Policy Statement 25
QMED	Median Annual Maximum Flood (m^3/s)
SAR	Synthetic Aperture Radar
SFRA	Strategic Flood Risk Assessment
SoP	Standard of Protection
SuDS	Sustainable Drainage Systems
SW	Surface Water
T&MBC	Tonbridge and Malling Borough Council
WwTW	Wastewater Treatment Works

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.

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1 Introduction

1.1 Study Objectives

The Environment Agency (EA) and Tonbridge and Malling Borough Council (T&MBC) have jointly commissioned Mott MacDonald to carry out a Strategic Flood Risk Assessment, (SFRA). The focus of the study areas was selected after the application of a sequential test as described in Planning Policy Guidance Note 25: Development and Flood Risk (PPG25)[1]. The sequential test used a multi-tiered approach to inform the draft future spatial strategy[2] for Tonbridge and Malling Borough, see Appendix B. The key planning constraints identified as part of the sequential test can be seen in Figure 1.2

The outcome of the sequential test found that virtually all of the future residential growth, which is anticipated to take place within the Borough during the next 15 years, outside of Tonbridge central area, will be in locations at no risk from flooding. However, in order to deliver key national, regional and local sustainable development objectives, particularly in relation to town centres and to respond to the outputs of local baseline studies, the test found that for some required development no reasonable options are available in Flood Zones 1 or 2. This applied to the regeneration of Tonbridge Town Centre and the proposed regeneration of Aylesford riverside. For these reasons, the focus of the SFRA is on Tonbridge and Aylesford because these areas are where future development or redevelopment is anticipated within a high risk flood zone. The areas are identified in Figure 1.2.

This report presents flood risk maps and hydraulic modelling output to appreciate the scale of flood risk within the two focus areas.

1.2 Government Advice on Flood Risk

The requirement to undertake a SFRA is set out in the emerging Government advice in PPS25[3]. In terms of interpreting the SFRA in relation to T&MBC's Local Development Framework, it is important that significant regard is paid to the advice in PPG25[4]. This is because PPG25 is the current Government planning policy on the issue of development and flood risk. Advice in PPS25 (still draft) is emerging and may be subject to change in the final version when it is published. Draft PPS25 also introduces the concept of the 'Exception Test' to be applied after the sequential test has been run and assessed. How this approach, if adopted by Government, will guide the preparation of T&MBC's Development Plan Documents (DPDs) and how it relates to the sequential test is set out in the 'SFRA and Local Development Framework' flow chart (see Appendix B).

[1] PPG25 (July 2001) 'Development and Flood Risk' para.30
[2] TMBC Preferred Options Report (September 2005)
[3] PPS25 (draft, December 2005) 'Development and Flood Risk' paras.11-12
[4] PPG25 (July 2001) 'Development and Flood Risk'

1.3 Primary Purpose of the SFRA

The SFRA is a constantly evolving document which uses the most up-to-date information to inform planning policy within the Borough Council. The primary purpose of the SFRA, in relation to the Local Development Framework (LDF), is to inform the preparation of T&MBC's Local Development Documents (LDDs), having regard to catchment-wide flooding issues which affect its area. The SFRA provides the information to assist the approach to allocation of development sites[5]. For T&MBC, the SFRA will initially inform the preparation of the first tranche of Development Plan Documents: the Core Strategy, Development Land Allocations and Tonbridge Central Area Action Plan.

The SFRA also sets out to:

- provide a detailed and robust assessment of the extent and nature of the risk of flooding in the specific areas of the floodplain where new development or redevelopment is likely to be proposed in the next plan period (to 2021).
- ensure the T&MBC meets its obligations under PPG25, and has regard to its successor PPS25 which is still in draft form.

1.4 SFRA Stages

The T&MBC SFRA has been carried out in two stages:

The Stage 1 study carried out in May 2006 concentrated on the collection and evaluation of hydraulic and topographic data which was readily available at the time of the study to provide information on flood risk in Tonbridge and Aylesford. The Stage 1 study identified the PPG25 Flood Zones using the existing data, and highlighted limitations in the data which would be addressed in Stage 2. The hydraulic modelling used within Stage 1 makes a number of assumptions which may affect the accuracy of the data provided. These limitations are outlined in Chapter 8. This work was considered adequate to inform strategic land use decisions for the LDF.

The Stage 2 work has updated the hydraulic modelling around the town of Tonbridge using new topographic surveys for tributaries of the River Medway, commissioned by Mott MacDonald. The revised hydraulic modelling refines the flows through the centre of Tonbridge by including detailed information for the three bypass channels, the Gas Works Stream, Botany Stream and Mill Stream. The model also takes account of the flood defences in and around Tonbridge. The study presents the Flood Zones identified in accordance with the guidance of PPG25 including allowance for climate change. The study also assesses the areas benefiting from defences within the study regions and will inform detailed decisions about the precise location and form of development in the town centre.

[5] PPG25 (July 2001) 'Development and Flood Risk' para.30

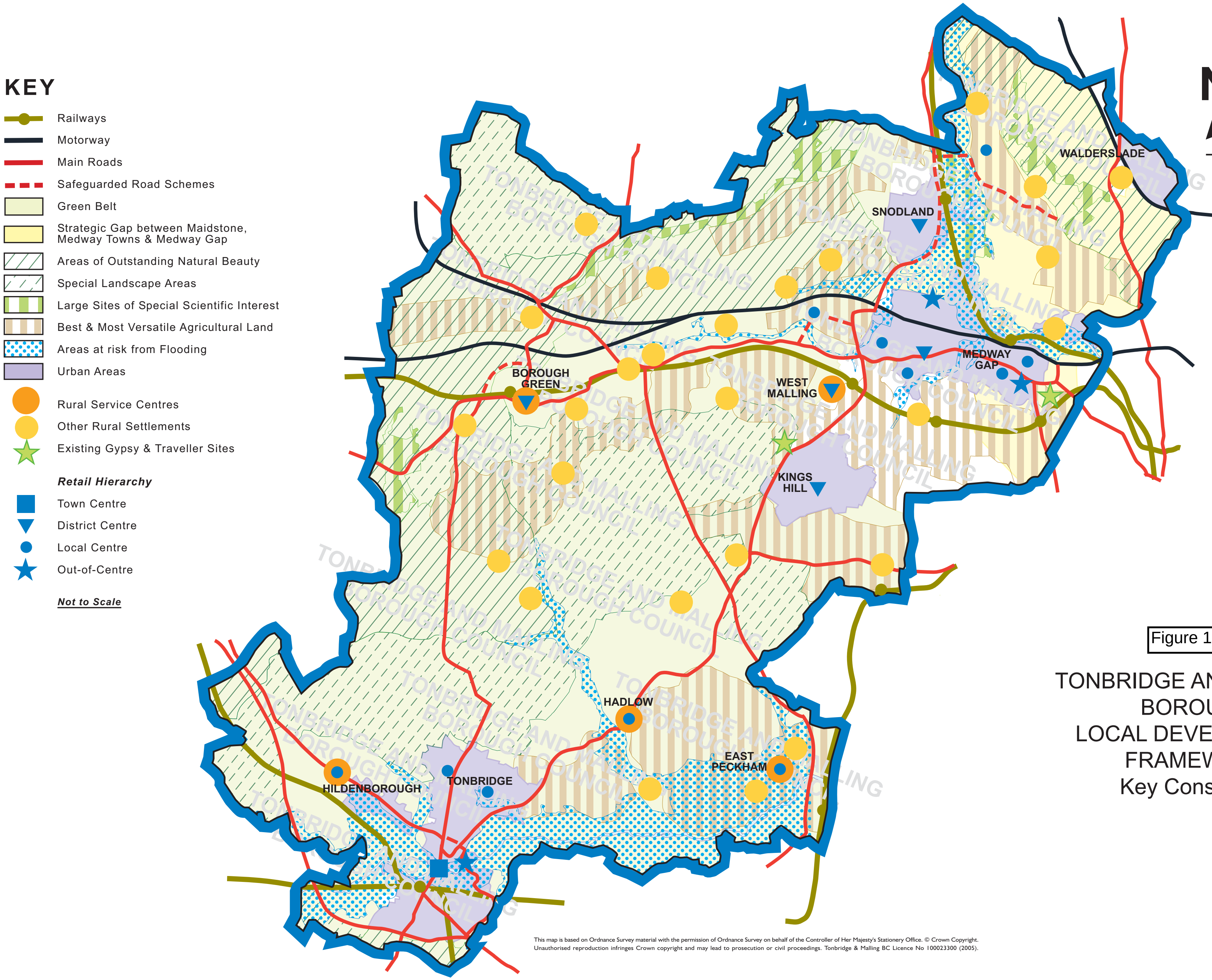
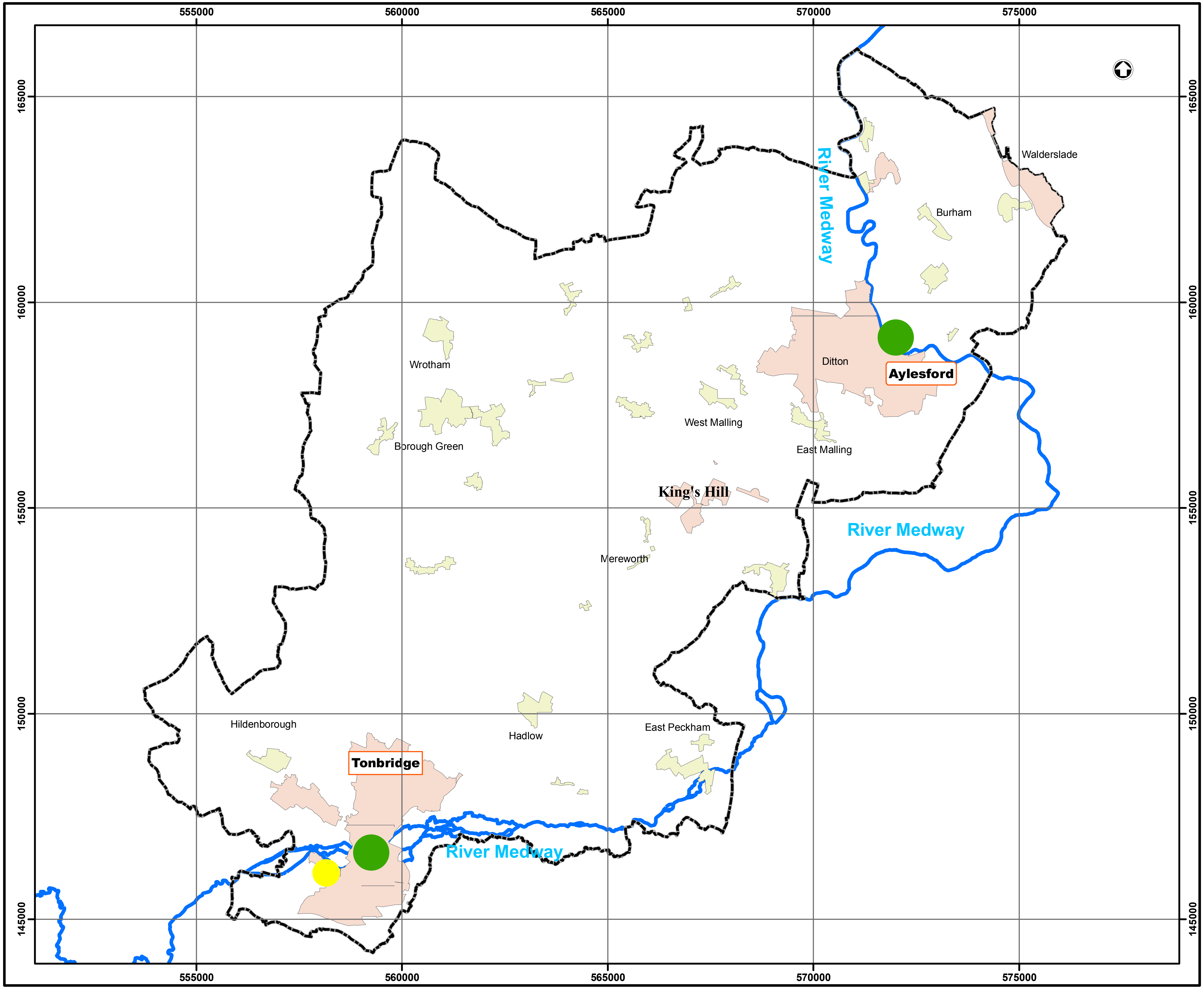


Figure 1-1

TONBRIDGE AND MALLING BOROUGH
LOCAL DEVELOPMENT FRAMEWORK
Key Constraints



LEGEND

Town

Village

Medway River and Tributaries

Borough Boundary

Proposed development areas focused upon in SFRA.

Safeguarded site possible Post 2021 development

Mott MacDonald

TONBRIDGE & MALLING BOROUGH COUNCIL

Tonbridge and Malling Borough Council SFRA

Figure 1-2
Location Plan

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2 SFRA Background Information

2.1 Data Collection and Verification

A vast amount of data has been collected for the Strategic Flood Risk Assessment. The data collected is outlined in the following chapters:

- Chapter 3: Ground Surface Data
- Chapter 5: Watercourse Data (River Medway, Botany Stream, Gas Works Stream, Mill Stream, Hilden Stream and Hawden Brook)

2.2 Interface with other Flood Risk Products

It is recognised that this SFRA is being carried out at a time when a number of other flood risk products have become available. In October 2004, the Environment Agency replaced its Indicative Flood Map (IFM), which had been in use for the past 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 PPG 25 Zones, as defined in Section 2.4 below. The EA issued the first edition of the Flood Zone Maps to Local Planning Authorities in June 2004, and these have been updated at regular intervals since then.

2.2.1 Differences between Agency Flood Zone Maps and SFRA Maps

The principal differences between the EA Flood Zone Maps and the SFRA maps is that the former do not take account of flood defences, whereas for the SFRA the effect of defences is specifically included; also the SFRA identifies the Functional Floodplain on modelled Main Rivers.

The Functional Floodplain within the T&MBC SFRA is taken as the extent of the 1 in 10-year flood event with an additional 20% flow to allow for climate change over a planning period of 50-years. This level was agreed upon after meetings with the EA and T&MBC.

In addition, there will be some differences arising from the different methodologies used to derive the zone boundaries. The SFRA has used results from detailed hydrological and hydraulic modelling of Main Rivers to obtain flood levels, and has combined this with ground level information which is sourced from photogrammetry techniques and ground survey data. The topographic data used for the SFRA is described in Chapter 3

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 Interferometric Synthetic Aperture Radar (IFSAR) techniques, giving a vertical accuracy of +/- 50cm. However, where better modelling is available, the EA have included the outputs in the Zone 3 extent.

2.2.2 The Extreme Flood Outline

The 1 in 1000-year flood extent outline for the Strategic Flood Maps (Flood Zone 2) has been taken from the EA Extreme Flood Outline (EFO) for fluvial flooding in the upper Medway. The EA emphasise the need for outputs of the SFRA to be compatible as far as possible with future EA mapping and the National Flood and Coastal Defence Database (NFCDD). Since the extreme flood outline forms an important part of the EA's new Flood Risk Mapping Strategy, there is a very strong case for its use in the SFRA. The EFO (Flood Zone 2 extent) is shown on the flood risk maps within this report.

The EFO takes no account of defences, as most man-made features have been removed from the digital terrain model (DTM) on which it is based. However, it is considered that this will make no significant difference to the 1 in 1000-year outline, since during such an event almost all defences would be completely overwhelmed.

The EFO has been produced for the EA by JBA Consultants. It uses a specially developed modelling technique called J-Flow to derive flood extents based on Flood Estimation Handbook (FEH) derived hydrology and a 2-dimensional flow spreading algorithm. The automated mapping process relies on a DTM created from the IFSAR survey undertaken by Intermap for the whole of England and Wales. This product is known as NextMap. The 1 in 1000-year outlines shown on the Tonbridge maps take account of modifications carried out by the EA whereby all substantiated historic flood information held by the EA has been included.

The 1 in 1000-year outline in Aylesford has been created using the hydraulic model described in Section 5-10 below.

2.3 Project Outputs

The principal project output from Stage 2 of the SFRA is the mapping of Tonbridge and Aylesford showing land classified to PPG25 Zones where possible. These Zones are as set out in Table 2.1: Flood Risk Zones in PPG 25 below.

The maps accompanying this report are at 1:5,000 scale and show land classified to the appropriate PPG 25 Flood Risk Zone 1, 2, 3a, 3b and 3c, using new modelling. The maps have been produced digitally with O.S. 1:10,000 scale mapping as a backdrop. In addition 1:5000 maps showing the extent of flooding taking account of flood defences are presented.

The map data will be supplied in a GIS format compatible with MapInfo & ESRI GIS, and are attributed to suit Environment Agency and Tonbridge and Malling Borough Council requirements.

The Flood Risk Zones are delineated on the maps by a colour scheme previously agreed with the Environment Agency. Light blue is used to show Zone 3 from detailed hydraulic modelling. The differentiation between Zone 3a (developed areas) and Zone 3b (undeveloped and sparsely populated areas) can be seen from the underlying O.S. mapping, provided by the EA. Zone 3c (the functional floodplain) is shown as light red shading.

Zone 2 is shown as dark blue and has come from the EA Flood Zone Maps around Tonbridge and from existing modelling in Aylesford. All areas at less risk than Zone 2 are classified as Zone 1. The boundaries between the zones are described in Section 2.4 below.

The defended 1 in 100-year flood extent has been further subdivided in and around Tonbridge to include information on the depth of flooding. The three sub categories are:

- High -Low Risk: flooding depth less than 20cm in a 100-year event
- High - Medium Risk: flood depth between 20cm and 50cm in a 100-year event
- High - High Risk: flood depth greater than 50cm in a 100-year event.

The SFRA outputs should be used in conjunction with the EA Flood Zone Maps. The Flood Zone Maps cover each watercourse with catchments greater than 3km^2 and therefore may provide an assessment on watercourses not covered by the SFRA.

The SFRA should be seen as a constantly evolving document. Improvements to modelling; changes to river channels; changes to the floodplain and changes to defences could alter results. It is the intention for the SFRA to be regularly updated to ensure the data remains the best available.

2.4 Flood Zones - General Criteria

It is required that Flood Risk Zones are defined in accordance with the criteria set out in PPG25. For land at risk from fluvial flooding, these criteria require differentiation according to the "sequential characterisation of flood risk" as shown below in Table 2.1: Flood Risk Zones in PPG 25 .

Table 2.1: Flood Risk Zones in PPG 25

Flood Zone	Level of Risk	Summary* of "Appropriate Planning Response"
1	Little or no risk. Annual probability of flooding < 0.1%	No constraints due to river flooding.
2	Low to medium risk. Annual probability of flooding 0.1 to 1.0%	Suitable for most development.
3a	High risk. Developed areas with annual probability of flooding 1.0% or greater	May be suitable for residential, commercial and industrial development provided the appropriate minimum standard of flood defence can be maintained for the lifetime of the development.
3b	High risk. Undeveloped & sparsely developed areas with annual probability of flooding 1.0% or greater	Generally not suitable for residential, commercial and industrial development unless a particular location is essential, e.g. for navigation and water-based recreational uses, agriculture and essential transport and utilities infrastructure, and an alternative lower-risk location is not available.
3c	High Risk. Functional floodplains.	Built development should be wholly exceptional and limited to essential transport and utilities infrastructure that has to be there.

* *For full details see Table 1 of PPG25.*

2.4.1 Zone 2 / Zone 3 Boundary

The principal criterion for differentiation between the PPG 25 Zone 2 and 3 in regions with fluvial flooding is the 1 in 100-year event in fluvial dominated regions (i.e. the Tonbridge area) and the 1 in 200-year event extent in tidal dominated regions (i.e. the Aylesford area).

The 1 in 100-year and 1 in 200-year flood extents outline for the Strategic Flood Maps have been obtained in accordance with the processes set out in Chapter 5 below.

2.4.2 Zone 1 / Zone 2 Boundary

The 1 in 1000-year flood outline defines the boundary of Zone 1 and Zone 2. For the Middle River Medway these have been taken from the same source as for the Environment Agency Flood Zones discussed in Section 2.2.2.

The 1 in 1000-year results for the Lower River Medway have been taken from hydraulic modelling discussed in Section 5.8. The division between Lower and Middle River Medway is the tidal limit of the River Medway at Allington Lock.

2.4.3 Zone 3c – Functional Floodplain

It has been agreed with the EA that the functional floodplain should be defined by the extent of the 10% (1 in 10-year) flood outline plus 20% flow. These flood outlines have been obtained using similar procedures as for the 1% outline.

2.4.4 Flood Risk Assessments for Individual Development Proposals

The T&MBC SFRA has concentrated on presenting a strategic picture of flood risk issues along the river corridor, however, to encourage sustainable development a site specific Flood Risk Assessment (FRA) should consider flooding issues relevant to a development proposal. The FRA should be proportionate to the size of development and the level of risk. In a commitment to improving the environment, a FRA should seek innovative ways of mitigation in order to reduce flood risk and facilitate high quality development within a particular site. As a minimum a FRA aims to ensure the implementation of a proposed development will not increase flood risk to the site or elsewhere.

In order to satisfy planning requirements, an FRA will need to demonstrate that a development is suitable for approval and that residual risks can be managed appropriately. Existing property owners may reasonably expect that their property should not suffer any direct detriment as a result of new development, or be subject to an unacceptable increase in flood risk.

A FRA is required for all development proposals within Flood Zones 2 and 3 and for a major development in Flood Zone 1, although the FRA in Flood Zone 1 is only required to determine the flood risk from surface water run-off. Major development is defined as 10 or more houses; or 0.5 Ha or more; or 1000 m^2 or more of industrial development. The applicant or promoter of a development is responsible for the production of the required FRA.

The range of issues to be considered by a FRA is set out in Appendix F of PPG 25. Particular attention should be given to the impacts of climate change and to the provision of safe evacuation measures.

2.5 Climate Change

Changes in flood risk and the implications for flood defence have been identified as one of the top five national concerns arising from climate change predictions. DEFRA has been providing guidance for incorporating sea level rise into the design of sea defences since 1989. The UK is also subject to post-glacial geological land movement. The DEFRA guidance combines these land movements with the sea level rise estimates to give a net figure for sea level rise.

It should be recognised that there is uncertainty in flood estimates, however, the accepted prediction for affective sea level rise due to global warming and land level adjustment for the Tonbridge and Malling Borough Council area is 6mm per annum.

In addition to sea level rise, climate change is also expected to result in an annual rainfall increase of between 0 and 10% by 2050 with autumns and winters becoming up to 20% wetter. It is also suggested that the number of rain-days and the average intensity of rainfall are expected to increase slightly and that average seasonal wind speeds could increase over most of the country.

From initial research, rivers and drainage systems could experience increases in peak flow of up to 20% for a given return period within 50-years. For the predominantly fluvial flood risk area within Tonbridge and Malling Borough this should be adopted as the allowance for climate change.

Appendix A of PPG 25 provides additional guidance on the likely impact of climate change, and the Planning Toolkit, prepared for the EA and the South East England Regional Assembly (SEERA), provides guidance on measures such as grey water systems and other specific water related climate change issues.

3 Ground Surface Data

3.1 Photogrammetry Data

As part of the Flood Risk Mapping Study of the River Medway, floodplain topographic information was collected by the Environment Agency using aerial survey techniques. The aerial survey was conducted in February and March 1997 for different parts of the watercourse and floodplain. The photogrammetric data was derived from stereo aerial photography at a scale of 1:3000 using detailed topographic techniques. This process provided contours at intervals of 250 mm within the floodplain. The contours were based on a 25 m by 25 m grid of spot heights supplemented by break lines to delineate ridges and depressions in excess of 0.5 m, as well as top and foot of embankments and cuttings where changes in slope occur.

The photogrammetric data was provided to the Consultant in Micro-station DGN and AutoCAD DWG formats. It was made available in three batches between 2000 and 2001. The total coverage of the photogrammetry data used for the SFRA is shown in Figure 3-1.

River cross section and longitudinal section data collected from the topographic survey was used to check the quality of the photogrammetric data. This was a simple means of validating the photogrammetric data for the areas where the two sets of information overlap. The checking exercises indicated that the two sets of data are reasonably consistent.

3.2 Ground Survey Data

Longdin and Browning Surveys were commissioned by Mott MacDonald in June 2006 to undertake a survey of Tonbridge town centre. The survey covered Gas Works Stream Botany Stream and Mill Stream, with an additional culvert study between Gas Works Stream and Botany Stream. Survey sections were taken in accordance with the EA National Specification for Surveying Services (Version 2.5).

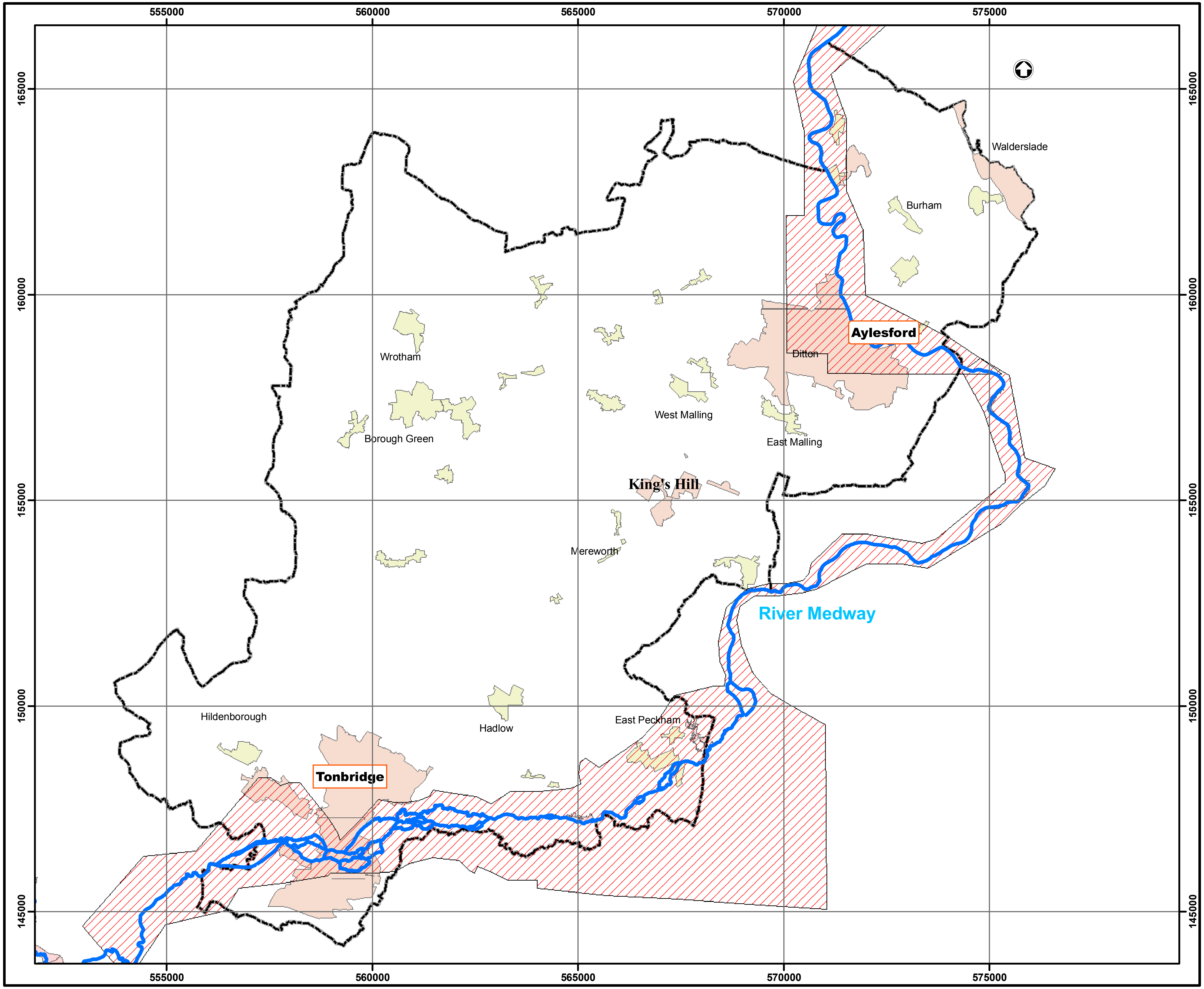
The survey included:

- 22 cross sections along Gas Works Stream
- 24 cross sections along Botany Stream
- 17 cross sections along Mill Stream
- a number of spot heights along key features within Tonbridge.

All structures influencing flows along the watercourses were surveyed, along with features influencing any overland flows. Figure 3-2 shows the location of cross sections and spot levels within the centre of Tonbridge.

3.3 Aerial Photography

A comprehensive set of aerial photographs were made available for the River Medway and the River Eden showing the extent of flooding during the October 2000 flood extent. The information assisted model calibration and flood mapping within the centre of Tonbridge.



LEGEND

- Town
- Village
- Photogrammetry extent
- Medway River and Tributaries
- Borough Boundary

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Tonbridge and Malling Borough Council SFRA

Figure 3-1
Extent of Photogrammetry

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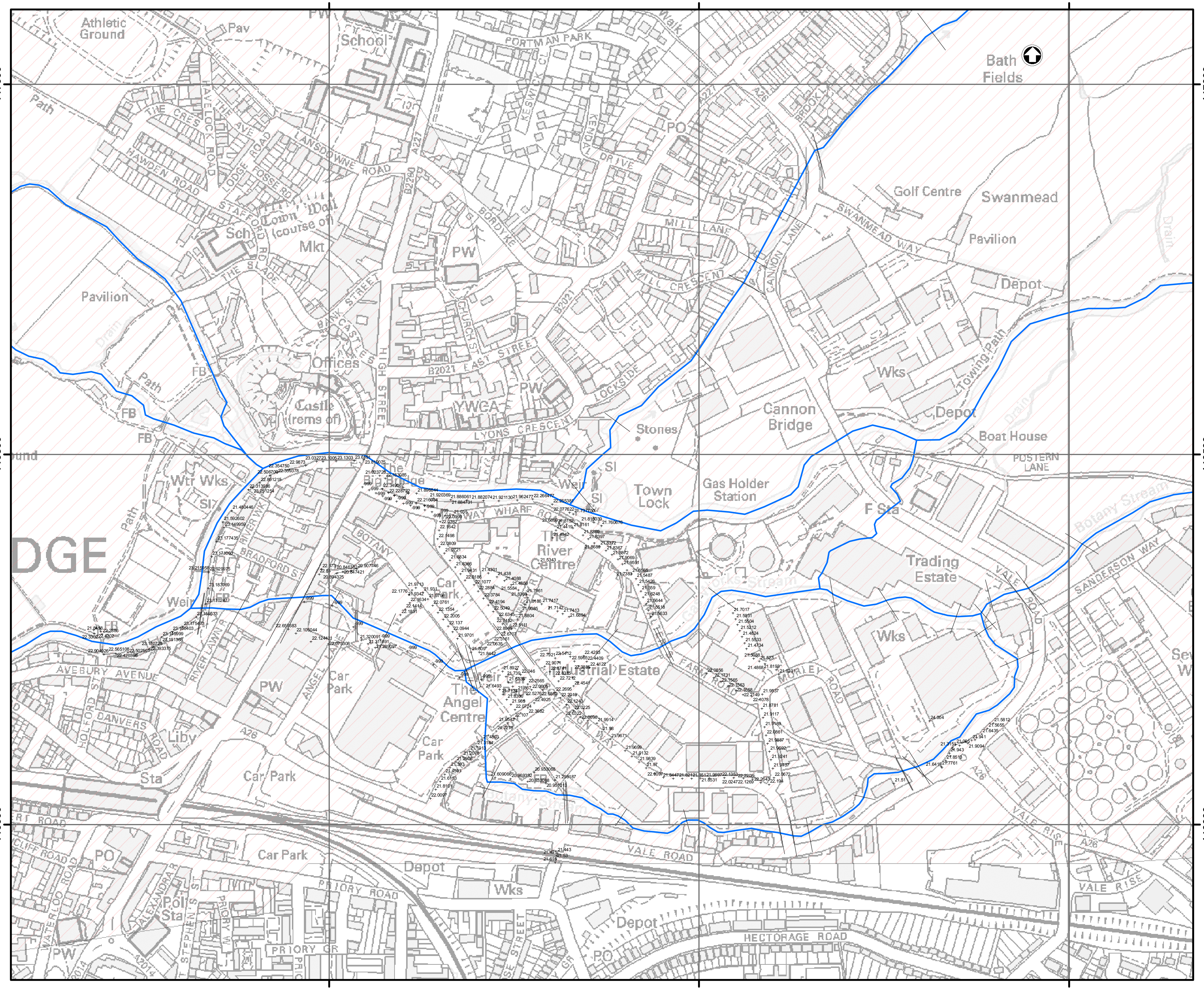

User Note

This plan has been produced in accordance with Section 105 (2) of the Water Resources Act 1991. Since the information is indicative rather than specific, users will need to consult the Local Council on individual planning applications. Users should note that the floodplain extents were mapped as appropriate to the level of investigation,and are based on information available at the time of survey. These maps are intended to be used for strategic planning and do not replace Environment Agency maps as the primary source of information for the public. (www.environment-agency.gov.uk/)
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. It should be noted that certain locations not shown to be at risk may still be at risk of flooding from other sources (pipe drainage systems, water mains etc.) and from other watercourse not modelled in this study.

LEGEND

Extent of Photogrammetry

Survey 1997

Spot Height in m AOD + 21.8

Cross-Section

Survey conducted June - August 2006

Medway River and Tributaries

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Tonbridge and Malling Borough Council SFRA

Figure 3-2

Tonbridge Town Centre Survey Location Plan

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4 Flood Defences

4.1 General

Flooding has historically been a problem in the Tonbridge and Aylesford, as they lie partly within the floodplains of the Medway. Following the flood of September 1968, which caused extensive damage to the town of Tonbridge, high flows in the River Medway are now regulated by sluice gates and a flood storage area at Leigh called the “Leigh Barrier”. The barrier, in combination with local flood wall defences, help protect Tonbridge from flooding.

The Leigh Barrier was constructed in 1981 to alleviate flooding to an estimated 1,100 properties in the Tonbridge area. Its construction was a response to the 1968 flood event which had caused severe flooding in and around Tonbridge. It has been in operation for 25 years and was instrumental in saving Tonbridge from severe flooding in the autumn 2000 flood event. The barrier comprises an earth embankment dam with a concrete control structure on the River Medway, plus various ancillary works. The control structure has three radial gates which can be opened and closed to control the outflow from the reservoir behind the embankment dam. The centre gate is 9.1 m wide. The north and the south gates have an equal width of 6.6 m.

The location of the Leigh Barrier and other flood defences around the potential development areas are shown in Figure 4-1. The operation of the Leigh Barrier is discussed briefly in Section 4-2 below; further details are given in Leigh Barrier Operating Procedures Review (2006), Ref 1.

In addition to the barrier, within the Medway catchment within Tonbridge and Malling Borough there are two main categories of flood defence:

• Inland Flood Defences – such as banks, structure walls and impounding reservoirs. This category of flood defence is used upstream of Allington Lock, i.e. the tidal limit of the river, nominally 3 km downstream of Maidstone.

• Tidal Flood Defences – such as earth embankments, structure walls, and sluice gates. This category of flood defence exists on the Medway between the tidal limit at Allington Lock and the relatively high ground on the Isle of Grain.

4.2 Leigh Barrier Operation

The Leigh Barrier control gates are operated to reduce the flow in the River Medway in times of flood, in order to reduce the risk of flooding in Tonbridge and associated settlements. The excess flow (the difference between flow into the reservoir and outflow from it) is stored temporarily in the reservoir up to a maximum storage level of 28.05m AOD.

However, in order to use the reservoir storage to optimum effect, it is necessary to predict the size and shape of the flood hydrograph as far in advance as possible. The secret of successful operation therefore is the ability to predict as accurately as possible the developing flood in terms of the following:

- the flow from the upstream catchment, its likely peak value, and the timing of the peak;
- the rate of increase in flow into the reservoir;
- the duration of the flood;
- the volume of the flood;
- the likelihood of subsequent peaks in the flood hydrograph; and
- the flow conditions downstream of the barrier during the course of the flood event.

The above list leads to plots of the flood hydrograph at several locations in the catchment, including upstream of the barrier, at the barrier, and downstream of the barrier.

4.2.1 Automatic Control

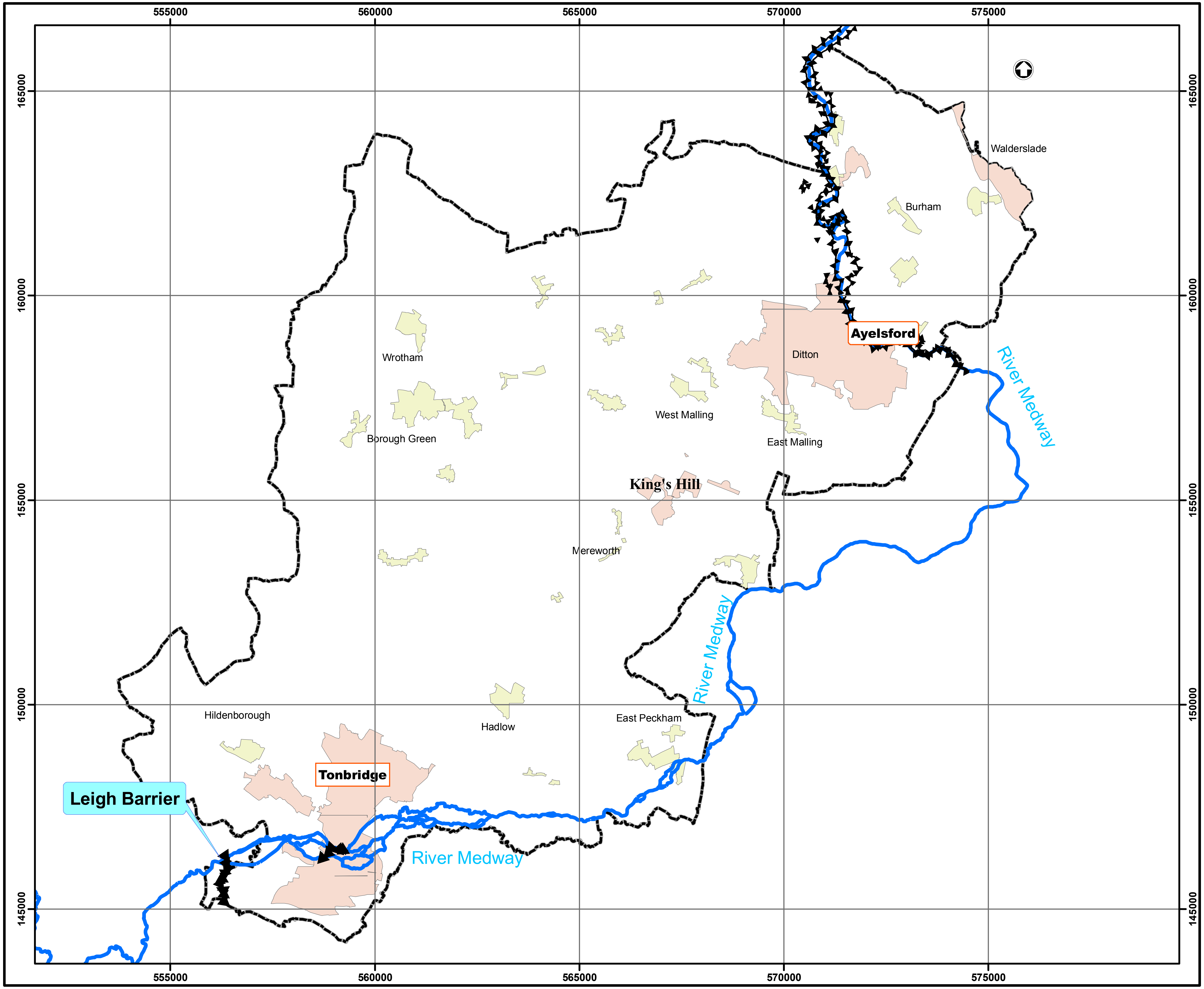
The term “Automatic Operational Rules” (or automatic control) in this report is used to describe the situation where no manual intervention takes place. The Leigh Barrier was set up such that automatic operation would take place when the river was not in flood, and in this mode the flow out of the reservoir would be limited to 32 m^3/s. The operating rules allowed for manual intervention when the predicted inflow to the reservoir reached 100 m^3/s, at which time the gates could be adjusted to allow the outflow to increase to above 32 m^3/s.

It should be appreciated that the option of allowing the barrier to be operated automatically throughout a flood event has never been an accepted procedure. Manual intervention always has been, and still is being used, to increase outflow from the reservoir in the developing flood, thereby increasing the effectiveness of the reservoir in reducing peak flow in the river downstream.

4.2.2 Leigh Barrier Operating Procedure

Section 5.9.2 discusses the operating procedure assumptions used in the hydraulic modelling of Tonbridge. For details of the Leigh Barrier Operating procedure see Leigh Barrier Operating Procedures Review (2006)[6].

[6] Mott MacDonald (2006), Leigh Barrier Operating Procedures Review



LEGEND

Town

Village

Medway River and Tributaries

Borough Boundary

Flood Defences

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Tonbridge and Malling Borough Council SFRA

Figure 4-1
Location of Defences

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5 Main River Data

The principal source of data for defining the Main River flood extents are the numerical modelling studies and flood mapping exercises which have been carried out over the last few years for the EA and local Authorities by Mott MacDonald. These studies are:

- River Medway Flood Risk Mapping, Phase 3 Study, 2004
- Medway Council SFRA Phase 1, 2006

5.1 Medway Catchment

The River Medway rises as a spring just above Turners Hill to the south-west of East Grinstead in East Sussex. The river flows north-eastwards towards Penshurst where it is joined by the River Eden which rises above Oxted in Surrey. As the Medway crosses the Vale of Kent it collects other tributaries from the High Weald including the Bourne, Teise, Beult and Len. The Medway then cuts through the Greensand Ridge beyond Yalding before reaching its tidal limit at Allington Lock in Maidstone. It then flows north cutting through the Chalk before the estuary widens out at Rochester. It finally joins the sea at Sheerness.

The geology of the catchment dictates the character of the River Medway and its tributaries. In the higher reaches of the Medway above Tonbridge the river system is characterised by many deeply incised tributaries which have cut through the underlying Hastings Beds. The alluvial plain associated with the river channels in this area is generally less than 500 m wide. The River Eden meanwhile flows along the north boundary of the Hastings Beds before joining the Medway. The River Eden is fed both by surface runoff from the clay and spring flow from the lower Greensand outcrop on the northern margin of the catchment.

Terrace deposits associated with the Eden spread onto the Weald Clay and are locally up to 1 km in width. Below Tonbridge the alluvial area widens to exceed 1km locally as a response to the predominance of the more eroded Weald Clay of the Vale of Kent. The alluvium is bordered by large areas of river brick earth together with remnants of former terraces lying up to 3 km from the present river channel. Downstream of the confluence with the River Beult, the River Medway passes through the Lower Greensand ridge via a narrow valley eroded through the Hythe Beds to the underlying Atherfield Clay. The alluvial plain bordering the river channel is of minimal width until, having passed through the Greensand ridge, the river crosses the Gault Clay vale downstream of Allington Lock and flows towards the Medway Gap in the North Downs.

5.2 Other Watercourses

The town of Tonbridge has a number of by-pass channels around various controlling structures along the Medway. These watercourses could have a significant impact on flood risk in the area. These watercourses have been modelled with the new hydraulic model, this is discussed in Section 5.9

5.3 Gas Works Stream

The Gas Works Stream is a bifurcation of the River Medway which flows through the centre of Tonbridge before the confluence with Botany Stream upstream of Vale Road. Gas Works Stream extends from OS 558822,146294 to OS 559881,146289.

Gas Works Stream is represented within the hydraulic model as a by-pass channel. Cross sections used in the model come from a survey carried out in July 2006.

Gas Works stream is crossed by a number of bridges and pipe structures, there are also two weirs, one at the Medway bifurcation and one downstream of the Botany Stream bifurcation.

5.4 Botany Stream

Botany Stream is a bifurcation of the Gas Works stream which begins in culvert under the Sainsburys car park. The watercourse re-joins the Gas Works Stream upstream of Vale Road and re-joins the River Medway downstream of Postern Bridge. Botany stream extends from OS 559182,146208 to OS 560220,146729.

Botany Stream is represented within the hydraulic model as a by-pass channel. Cross sections used in the model come from a survey carried out in July 2006.

Botany Stream is crossed by a number of bridges and pipe structures.

5.5 Mill Stream

Mill Stream is represented within the hydraulic model as a by-pass channel and an inflow calculated using FEH rainfall-runoff method.

Mill Stream is represented within the hydraulic model as a by-pass channel. Cross sections used in the model come from a survey carried out in July 2006.

Mill stream is crossed by a number of bridges and a mill between mill lane and cannon lane.

5.6 Hilden Brook and Hawden Stream

Hawden Stream is a tributary of Hilden Brook which it joins approximately 500 m upstream of the confluence of Hilden Brook with the River Medway. The total catchment area of Hawden Stream is 2.2 km^2.

A combined 1D hydrodynamic model for Hilden Brook and Hawden Stream was constructed by Mott MacDonald in 2005. The ISIS modelled covered approximate 3 km of channel in total. The ISIS model used the rainfall-runoff model based on procedures described in the Flood Estimation Handbook (FEH) to calculate design inflows for the model. Output from this model was used within the new modelling.

The reach of Hilden Brook included in the model extends from Ordnance Survey (OS) co-ordinates 558655, 147599 to its confluence with the River Medway at OS 558913, 146490. The reach of Hawden Stream included extends from the upstream end of a culvert at approximately OS 557288, 148035 to its confluence with Hawden Stream at OS 558593, 146868.

Tonbridge swimming pool, at the downstream end of Hilden just before it joins onto the River Medway, has a flood wall and gates giving a level of defence of 23.4 mAOD.

5.7 Hydraulic Modelling

The use of computers to model river systems is a powerful tool in river engineering. The model can be subjected to various storm events, and the behaviour studied. Extreme storm conditions can be replicated in design flood events and flood defence schemes tested in extreme without any risk.

Where possible, the model is verified from actual rainfall data (and data from flow gauging stations where available), and records of actual flooding events. Data is often sparse, however, and theoretical calculations of runoff into the rivers are limited in accuracy

With river modelling, the hydraulic conduit (the river), changes capacity with water level. The flow may leave the banks, either to be stored during the flood event within a reservoir area or finding its own way downstream via a lateral overland flow.

The behaviour of hydraulic controls and constraints may change during a storm event as the river levels change. As a result, the output of river modelling is less certain than other forms of modelling, and requires much more data in the form of flood channel survey to set up the model.

5.8 River Medway Flood Risk Mapping, Phase 3 Study, 2004

In 2004 Mott MacDonald, as part of the Mott MacDonald/Posford Haskoning consortium, undertook a study of the River Medway/Eden under the National Flood Risk Mapping Framework Agreement (NATCON 257). The model was produced using hydraulic modelling software called ISIS. The ISIS hydraulic model for the River Medway extended from Forest Row to Allington (Maidstone) and the River Eden from Edenbridge to its confluence with the River Medway at Penshurst.

This model was used to predict water levels and the extent of flooding for the town of Tonbridge. The design events from this model which have been used within Stage 1 of the SFRA are: 1 in 25-year, 1 in 100-year and 1 in 100-year (maximum – Leigh Barrier jammed open)

5.8.1 Model Approach

The 2004 ISIS model of the Medway was based on a previous Middle Medway ONDA model developed during the Regime Study in 1994/95. The ISIS study updated the floodplain data using photogrammetry data surveyed in 1997, as discussed in Section 3.1.

The ISIS Medway model required the hydraulic model to be extended further upstream: to Forest Row on the Medway, and to upstream of Edenbridge on the River Eden. Inflow hydrographs for the extended reaches of the hydraulic model were calculated using the rainfall-runoff methods described in the Flood Estimation Handbook (FEH). The Flood Studies Report (FSR) rainfall-runoff method is substantially similar in the updated Flood Estimation Handbook (FEH), therefore no further rainfall-runoff modelling was undertaken downstream of the upstream limits of the original Middle Medway model. Instead the inflow hydrographs used in the Regime Study were used for calibrating and verifying the converted and upgraded Middle Medway model.

The main purposes of the hydraulic modelling under this study were: (i) to predict flood water levels for floods of different return periods under normal operating conditions, and (ii) to predict the worst possible flood water levels for flood risk mapping purposes.

To predict the worst possible flood water levels it was assumed that the Leigh Barrier would not be working correctly as a flood defence. The scenario simulated the Leigh Barrier gates jammed open during a 1 in 100-year event.

5.8.2 Calibration

The Upper Medway/Eden model was calibrated and verified against five events. The downstream conditions used for calibrating and verifying the Upper Medway/Eden model were derived from the Middle Medway model. The key hydraulic calibration parameters included:

• Manning’s ‘n’ values for the river channel and floodplain;

• Coefficients for spill units, normally representing roads, embankments or high ground linking storage cells;

• Discharge coefficients for structures, such as weirs, locks and sluices;

• Loss coefficients for bridges.

The initial model calibration parameters were estimated according to the recommended literature values and experience. They were further adjusted or refined by using engineering judgement and common sense so as to achieve a better match between the model predicted water levels and the observed flood levels and profiles.

As part of the EA's flood risk mapping programme, mathematical models (S105 FRM models) are used to map flood extents. In the Medway model, operation of the Leigh barrier was simplified by adopting the automatic rules described in Section 4.2.1. Although this did not result in an outflow regime that matched historic operation of the barrier, this conservative approach was considered acceptable for the purpose of flood risk mapping.

5.8.3 Flood Mapping

The extent of flooding was determined by identifying the intersection of the design water levels with the topography of the area. This was carried out using the mapping software 12d. Isolated islands not connected to the river were then removed from the flood extent by hand. Further checks were then made during site visits to areas where the outlines were in doubt.

Users should be aware that the flood mapping prepared for the River Medway Flood Risk Mapping Study was derived by taking the maximum water levels for the given flood scenario predicted by the hydraulic model and mapping their intersection with the digital elevation model (DEM). The original DEM was created from the photogrammetric data collected in 1997, and thus did not include any changes to the local topography that have arisen since then, for example, due to the construction of new roads or embankments. As part of the T&MBC SFRA new survey data commissioned by Mott MacDonald was incorporated within the DEM and the outlines redrawn.

5.9 Modifications to River Medway, Phase 3 Study, 2006

As part of the T&MBC SFRA the River Medway ISIS model was updated to include:

- data from the ground survey commissioned by the Mott MacDonald in June 2006;
- flood attenuation from the operation of the Leigh Barrier;
- the model output from the Hilden and Hawden Brook ISIS model.

The main purposes of the hydraulic modelling under this study were to: update the flood water levels in and around the town of Tonbridge for different storm events and take account of the flood defences in and around Tonbridge including the Leigh Barrier.

5.9.1 Model Approach

The updated ISIS river modelling for the T&MBC SFRA runs from Leigh Barrier to Oak Weir Lock. The model is based on the River Medway Phase 3 ISIS model, discussed in Section 5.8. The modified model concentrates on the town of Tonbridge and includes new survey data from the Gas Works Stream, Botany Stream and Mill Stream. The Medway Phase 3 ISIS hydraulic model was truncated to increase model stability when adding features around Tonbridge.

The floodplain data for the updated model came from an amalgamation of the 1997 photogrammetry data with ground survey data taken during July/August 2006. The new ground data includes levels along new roads and developments since the 1997survey.

Flood attenuation from the operation of the Leigh Barrier has been incorporated into the revised model by using hydrographs derived from the LEBOP study; these are discussed in Section 5.9.2 below. The barrier forms the upstream limit of the revised model. The processed hydrographs simulate the flood routing through the Leigh Barrier.

Inflow hydrographs for Hilden and Hawden Brook have been updated using the Phase 3 2005 ISIS model, discussed in Section 5.6.

5.9.2 Leigh Barrier Inflow

As stated in Section 4.2, the Leigh Barrier control gates are operated to reduce the risk of flooding in Tonbridge and associated settlements.

The actual operation of the Leigh Barrier follows the original procedures up to an approximate inflow into the reach of 35 m^3/s. As flow into the reservoir reach rises to 35 m^3/s the operators switch the control gates to manual operation. The switch to manual operation takes place because the River Medway Flood Relief Act states that at an incoming flow of 35 m^3/s impounding may take place.

In 2005 Mott MacDonald were commissioned by the Environment Agency Southern Region to develop and test revised operating procedures of the Leigh Barrier, within the Leigh Barrier Operating Procedures Study (LEBOP). The findings from this study can be seen in Ref 1. Investigations were carried out to assess whether the original rules could be modified to provide an effective means of operating the Leigh Barrier in flood conditions. The study also looked at three “Options” for replicating the Leigh Barrier outflow hydrograph based on new operating procedures.

Outflow hydrographs from the Leigh Barrier are required to replicate the attenuation of flood waters, within the new hydraulic model. Outflow hydrographs for the Leigh Barrier are available for a few flood events; however as design flood events are required (i.e. 1 in 100-year), these need to be generated. The purpose of the option tests carried out in the LEBOP study was to assess whether an option can be found which would allow more flexibility than the automatic rules with a fixed outflow, and be less complex than the outflow calculation based on event characteristics.

These options were compared against five historic events to validate the models.

Option 1): Option 1 used automatic rules to simulate the outflow from the Leigh Barrier. As previously discussed these are an over-simplification of the current operating procedures, and would not be used in practice.

Option 2): Option 2 used a multi-regression analysis between the inflow hydrograph, the reservoir level and the outflow for five calibration events. The inflow was derived from the Medway Phase 3 ISIS model, run with observed inflow hydrographs at Collier’s Land and Vexour. The outflow was derived by converting the observed stage downstream of the barrier into flow, and the reservoir level was the observed stage upstream of the barrier.

This method provided the closest representation of the recent Leigh Barrier operating procedures. However, as this method is based on only a few events the outflow would fail for events with large volumes such as the 100 and the 50-year design events, the triple-peak event and extreme events. In all these cases the calculated outflow would be too small and the reservoir level would rise above its designed maximum level.

Option 3): Option 3 considering only the reservoir level to calculate the outflow, the study concluded that this option provided the best results. Using the suggested level – outflow relationship would only cause the reservoir level to rise above its designed maximum level of 28.05 mAOD for extreme events.

This method is slightly conservative as it produces a hydrograph with a larger maximum flow than would be expected. This is due to operators opening the gates to a greater extent during the development of a storm event. However the method provides the most robust method of producing Leigh Barrier outflows for design events.

To take account of the Leigh Barrier within the revised ISIS model design outflows from “Option 3” were used as a model inflow.

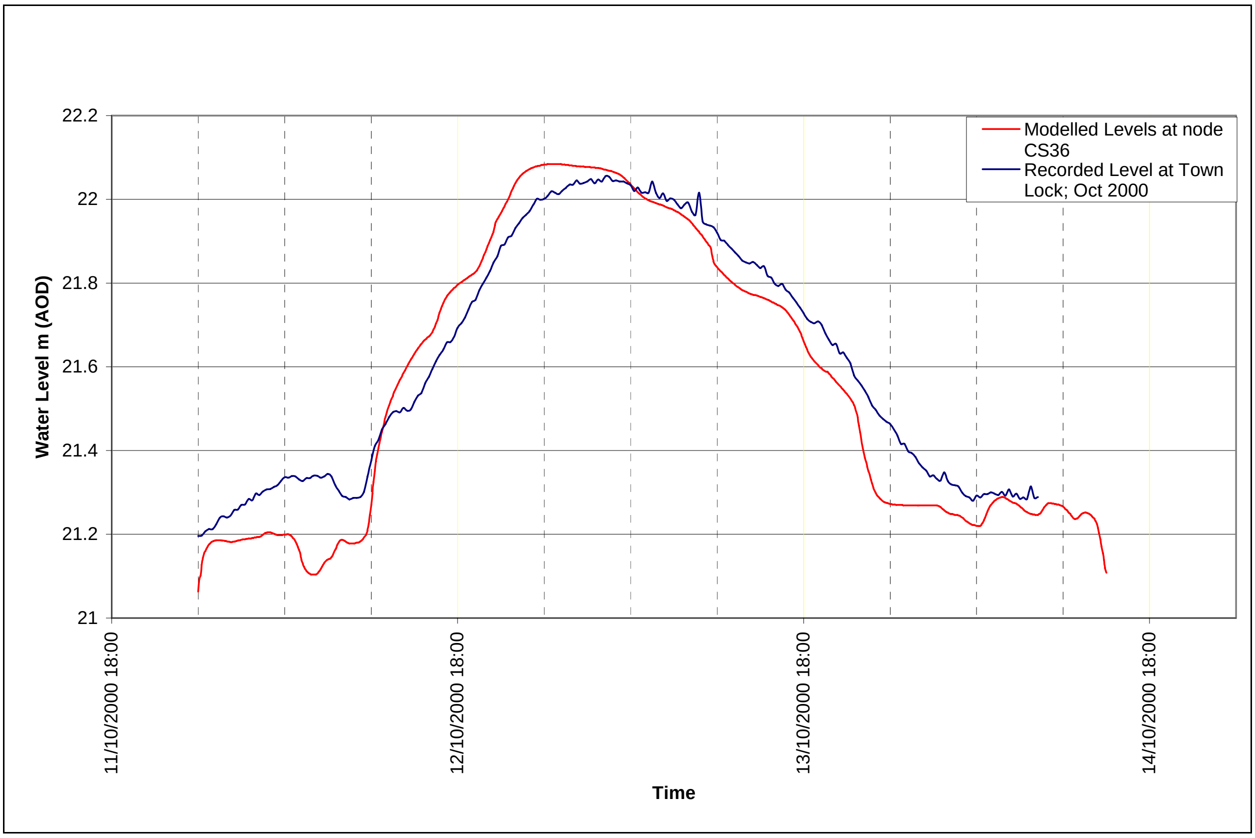
5.9.3 Calibration

To provide a greater understanding of the mechanism of flooding within an area, past events are examined and used to calibrate hydraulic models. Due to major changes in the river channels and floodplain in recent years, the October 2000 event provides the best calibration data. The observed levels at the town lock gauging station during the event on the 12 and 13 October were compared to the modelled levels at the same location.

The calibration model used observed discharge levels from the Leigh Barrier and modelled discharge from Hilden and Hawden Stream as inflows within the model. Comparison of the levels at Town Lock can be seen in Figure 5.2.

The initial model calibration parameters were estimated according to the recommended literature values and experience. They were further adjusted or refined by using engineering judgement and common sense so as to achieve a better match between the model predicted water levels and the observed flood levels and profiles.

Figure 5.1: Calibration of Model at Town Lock Tonbridge: Oct 2000 event



5.9.4 Interpretation in the vicinity of Control Structures

For the purpose of the SFRA it is important to note that the Medway has a large number of control structures (sluices and gates) that have a local influence on water level. To fully account for this would require 3-D modelling, therefore there are limitations to the maps and model predicted water levels that arise from using a 1-D approach.

The typical structure comprises a sluice gate and weir and either a navigation lock or a bypass channel. In some cases only the gate or sluice on the main channel has been included in the hydraulic model. When flows are in-bank, the model reach naturally shows a drop in predicted water level across the structure, but this would not be an accurate reflection of the level in the parallel bypass channel where there is no drop structure. Once the flood water comes out of bank immediately upstream of the structure it often bypasses the structure, the overland flow path often dictates the flooding extent and hence flood level on the flood plain. Such a bypass system is present in Tonbridge, see Figure 5-2 and Figure 5-3. In preparing the 100-year outline maps, the effect of local flow paths has been taken into account so that the mapped extent on both banks does give a reliable indication of likely flooding, rather than just reflecting peak water levels from the hydraulic model.

The by-pass channels were significantly updated during Stage 2 of the SFRA using new topographic data in Tonbridge and new defence height information.

Figure 5.2: Schematic of flows path through Tonbridge from the Medway Model Phase 3

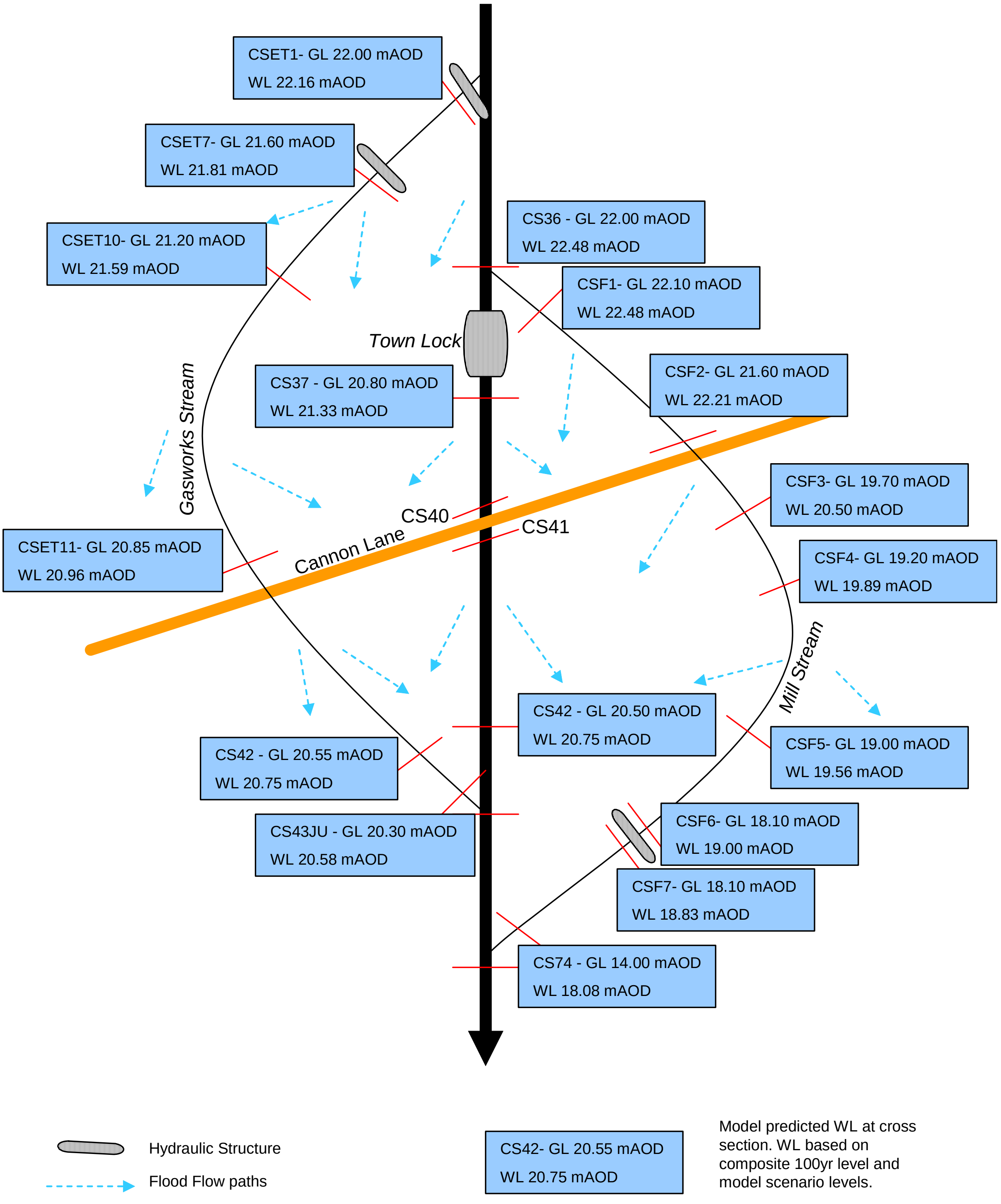
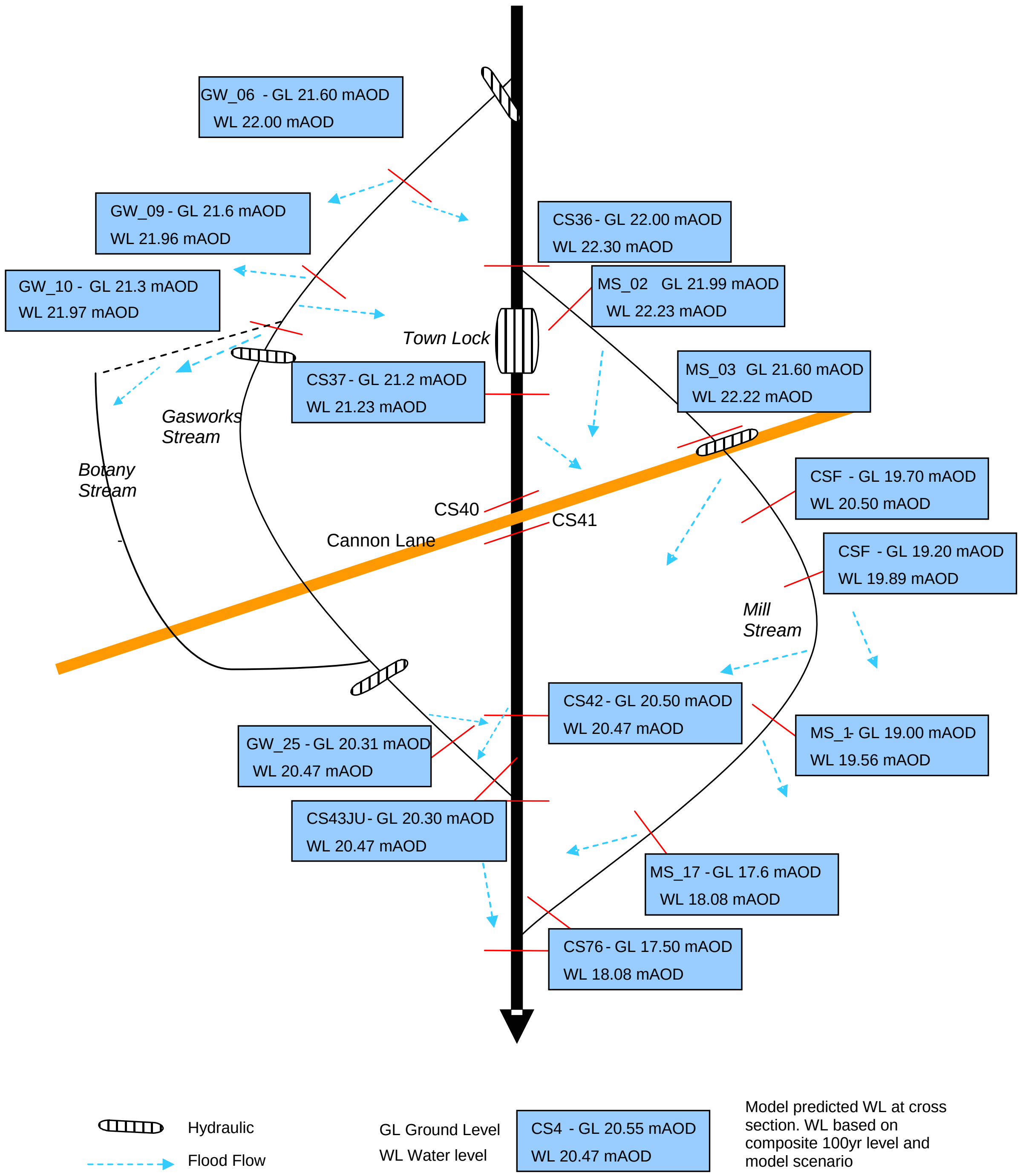


Figure 5.3: Schematic to Illustrate Flood Flow Paths of the revised model through Tonbridge.



5.9.5 Flood Mapping

The extent of flooding was determined by identifying the intersection of the design water levels with the topography of the area. This was carried out using the mapping software ArcView. The resulting flood extent was cross-checked against the model results for consistency. Further checks were then made during site visits to areas where the outlines were in doubt. Due to the topography of the area and drain connectivity within the town, isolated islands of flooding not connected to the river have not been removed.

Users should be aware that the flood mapping prepared for the T&MBC SFRA was derived by taking the maximum water levels for the given flood scenario predicted by the hydraulic model and mapping their intersection with the digital elevation model (DEM). The DEM was created from the photogrammetry data collected in 1997, with additional levels from the Tonbridge ground survey conducted in summer 2006. A plan of additional ground levels added to the Tonbridge Digital terrain model can be seen in Figure 3-2.

Flooding in and around Tonbridge was mapped in three stages. This involved producing three separate water surfaces (i) Medway River and Mill Stream, ii) Gas Works Stream iii) Botany Stream) to ensure the levels produced by the model were interpolated correctly. The intersection between the water surfaces and the ground level was then used to identify the flood regions. Additional cross sections were used at some structures to replicate the headloss at these structures.

As discussed in Section 5.9.4, the mapping has taken into account the effect of flow paths.

Historic ancillary data has also been used to supplement the flood outline produced from the hydraulic modelling. Information from aerial photos taken during the October 2000 flood and reports from people present during the event have identified additional areas prone to flooding. The source of flooding in these areas could come from a various sources including: main rivers; drains or pooling of rain water.

5.10 Medway SFRA

5.10.1 Modelling Approach

As part of the SFRA recently undertaken for Medway Council, a hydraulic model of the lower River Medway and its floodplain was developed using TUFLOW software. The River Medway TUFLOW model comprises a one-dimensional (1D) model of the river channel combined with a two-dimensional (2D) model of the floodplain and the other channels or streams/creeks. The 1D model of the river and the 2D model of the floodplain are dynamically linked, and water can flow from the 1D model to the 2D model and vice versa as appropriate. The 1D component of this study was based on the River Medway Mapping Study Phase 4 model.

The TUFLOW model extends from Allington Lock to Gillingham and provides the most up-to-date information on potential flood risk around Aylesford.

The design flood events analysed using the model were: a 1 in 200-year and 1 in 1000-year tidal flood under present conditions and allowing for future climate change. The climate change results are for 2060, allowing a 6mm rise in sea levels per annum.

5.10.2 Boundary Conditions

The tidal surge profiles used for the design runs and scenario tests were based upon a Gaussian distribution with a half width of 6 hours as provided by WS Atkins and approved by the EA. The peak of the surge profile provided was assumed to coincide with the peak of the astronomical tide for all the scenarios. However, in reality the magnitude and duration of the surge profile will vary from event to event.

The design peak levels used at the downstream boundary of the model were interpolated from the peak levels at Sheerness and Gillingham Port. The water level difference between Gillingham and Sheerness remains the same (0.35 m) for floods of all return periods as suggested in the Extreme Sea Level study Ref 2.

Boundary conditions used for climate change scenarios used a 6mm rise in sea levels per annum based on the Extreme Sea Level study Ref 2. All the design runs are based on a 1 year fluvial return period, although sensitivity runs were undertaken to show the effect of a 100-year return period fluvial flow.

5.10.3 Calibration

Observed data is essential to the model calibration and verification. However, due to the limitation of available flooding record data, it was agreed with the EA, only the February 1953 and January 1978 events would be used as model calibration events.

The tidal flooding of February 1953 was the most disastrous on record for the Medway estuary. A tidal surge in the north sea raised the tide almost two meters above its predicted level. Rivers and sea defences were breached in over three hundred places. The January 1978 flood was the most recent flooding event to have occurred on the Medway estuary. However, the magnitude and extent of flooding then was considerably less than the February 1953 event. Large floods are rare. Because of their rarity it is desirable to make the best use of the available historical data. Therefore, the observed water level profiles and flood inundation maps for these two large events were obtained and used to calibrate the model.

Calibration of the model around Aylesford showed that the predicted levels were approximately 30cm below the observed levels from the 1957 flood event and 10cm below the 1978 flood event. Such a discrepancy might be caused by a combination of factors, including the possible inaccuracy of the inflow used at Allington for this event (there was no observed flow for this event), and most likely due to the changes of the flood defences since 1953.

Following the 1953 flood, flood defences had been improved along the Medway estuary but with varied levels of protection.

5.10.4 Flood extent

As detailed topographic data from the floodplain is included in a 2D hydraulic model the extent of the flooding is identified during the modelling process. The extent of flooding extends from the channel into the floodplain and the extent and depth of flooding can be easily identified during the flood event.

6 Tonbridge

The town of Tonbridge is situated on the floodplain of the River Medway. The centre of the town is built around the River Medway and the tributaries: Gas Works stream, Mill Stream and Botany Stream. A large section of the town including the town centre is shown within Zone 3 on the EA Flood Zone Maps. These do not provide a precise picture of the current flood risk within the town as flood defences are not included, but provide an indication where greater investigation is required.

Flooding has historically been a problem in Tonbridge. The flood of September 1968 caused extensive damage to the town. Flooding within the town is now restricted by flood defences which work in combination to protect the town centre. High flows in the River Medway are now controlled by sluice gates and a flood storage area at Leigh discussed previously. Within the town itself there are flood walls which are built along the banks of the Medway.

Even with the presence of flood defences, the town of Tonbridge is not completely protected from flooding. During the winter of 2000/01, the Leigh barrier was operated more than ten times due to heavy rainfall on the upper Medway catchment. Flooding of Tonbridge from storms during October 2000 can be seen in Figures 6.1 and 6.2. These photos were used in the process of editing the flood maps produced from the hydraulic model, see Section 5.9.5.

This Chapter presents results from the revised modelling of the Medway and demonstrates the benefit of flood defences in Tonbridge.

6.1 Flood Risk Areas - Tonbridge Town.

The main flood risk to the town of Tonbridge comes from the main rivers: River Medway, Gas Works Stream and Mill Stream; however the other watercourses and drains could also pose a significant flood risk. The mapped extent of flooding within Tonbridge under different scenarios can be seen in Appendix C.

The term "defended" (below) identifies that the mapping and modelling has taken account of flood attenuation from the Leigh Barrier and the defence walls along the banks of the River Medway.

The term "undefended" (below) identifies that mapping and modelling has **not** taken account of flood attenuation from the Leigh Barrier and defence walls along the banks of the River Medway.

C-1 shows:

- the extent of the flooding during a defended 1 in 100-year event. The model used to derive the water levels is discussed in Section 5.9.

C-2 shows:

- the extent of flooding during a defended 1 in 100-year event, divided into three levels of risk, High-High > 0.5m depth of flood water , High-Medium 0.2m – 0.5m depth and High-Low < 0.2m depth.

C-3 shows:

- the extent of flooding during a defended 1 in 10-year event with an additional 20% flow to allow for climate change (see Section 2.5). The area covered by the 1 in 10-year event with an additional 20% flow defines the extent of the functional floodplain for the purpose of the SFRA.

C-4 shows:

- the extent of flooding during a defended 1 in-100 year event with an additional 20% flow added to account for climate change (see Section 2.5).

C-5 shows:

- the undefended 1 in 100-year outline (Flood Zone 3). The model used to derive the water levels is discussed in Section 5.8. It also identifies the additional flooding during a 1 in 1000-year event (Flood Zone 2)

C-6 shows:

- the development quarters in central Tonbridge with the extent of flooding during a defended 1 in 100-year outline, overlay.

6.1.1 Tonbridge Flow Paths

The current Flood Zone 3 within Tonbridge can be seen in Figure C-5; however the outline does not take account of flood attenuation or flood defence walls, this can be seen in Figure C-1. Flood defence walls along the right bank of the River Medway restrict flood water entering the town of Tonbridge during a 1 in 100-year event, however the levels in the Medway reach the crest of the flood defences along Medway Wharf Road. Comparison of water levels and defence levels in Tonbridge show that there is no freeboard during a 1 in 100-year event. In these circumstances there is a possibility that flood waters may wash over the defences due to waves along the river. This load on the defences may lead to them failing in places.

The Tonbridge defended 1 in-100 year model shows that flooding within the town centre comes from both the Gas Works Stream and River Medway. Flood waters from the Gas Works Stream flow across the Sainsbury’s car park and into Botany Stream and north towards the Medway. The majority of flooding takes place upstream of the weir. The topography of the area and drain system means that there is a possibility of water coming out of the drains in a flood event. This water would form pools in low-lying areas such as the River Centre Industrial Estate.

A large amount of predicted flooding can also be seen between the River Medway and Mill Stream, with an existing industrial estate affected. New development on the left bank of Mill Stream is shown within the floodplain, however the threshold levels for those properties is above 23.15 m, while the water level is 22.3 m AOD.

The figures show that when flood attenuation from the Leigh barrier is included there are three developed areas still prone to flooding in a 1 in 100-year event. These are between Mill Stream and the River Medway and between Angel Lane and Botany Stream. The latter flooded area is within the potential development area called the “Botany Quarter”. The third area is between the Gasworks Stream in the vicinity of the Waitrose car park and Medway Wharf Road. The flooding in this area follows the path of a previous open channel which is now in culvert.

6.2 Potential Re-Development in Tonbridge

The centre of Tonbridge is being considered for major redevelopment and regeneration. The main area where this development is planned is called the Botany Quarter. The Botany Quarter is bounded to the north by the River Medway, the west by the High Street, the south by the railway line and the east by Vale Road. The Master Plan for Tonbridge prepared by David Lock Associates (Ref 3) states *"the "Botany Quarter" presents the greatest opportunity to strengthen the town centre. Whilst the High Street presents a cohesive element of the urban realm, to the rear there is an immediate gap before Sainsburys is reached."* The Master Plan also states the importance of watercourses *"…the presence of the bridges, which draw people to the water, provides an inherent opportunity to utilise the town centre's extensive waterside to aide regeneration."*

The area of Tonbridge designated as "Botany Quarter" can be seen in Figure C-6. From Figure C-5 it can be seen that majority of the development area is currently within Flood Zone 3, with the defended outline in Figure C-6 still identifying large areas at risk of flooding. This does not prohibit development from taking place. It does however highlight the fundamental need for future development proposals to take account of the significant flood risk and bring forward mitigation proposals that can be integrated with the development and employ imaginative solutions to deal with flood risk management in this priority area for regeneration in the town centre.

Previously developed land which is vulnerable to flooding is discussed in paragraph 35 of PPG 25 (Ref 4) . The guidance states: *"In making proposals for redevelopment of such land or the re-use of existing buildings and structures, local authorities should take account of the risks of flooding, the standards of existing flood defences and the ability to improve them. Any such redevelopment should avoid interference with flood plain flows or compromising future shoreline or river management options. Developers and local planning authorities should consider what types of new development would be appropriate to these circumstances. For example, a site may not be sufficiently well defended to make it suitable for housing over its full area, although it might still be possible to incorporate housing within a mixed-use scheme, utilising parts of a site at higher risk of flooding for open space or other recreational provision."*

The document goes on to identify: *"The acknowledged risks of flooding might be mitigated by confirmed good levels of protection, including protected access, prudent design of development and effective public warning mechanisms. Sites vulnerable to rapid inundation should defences be overtopped or breached are unlikely to be suitable for those of restricted mobility, whether in conventional, adapted or sheltered housing or in institutional accommodation."*

Chapter 9 below discusses potential mitigation measures when planning development within T&MBC.

6.3 Flood Risk Zones - West of Tonbridge

To the west of Tonbridge there is a site which has been safeguarded to meet development needs after 2021. This area is to the north of Lower Haysden Lane, shown in Appendix D.

Figure C-7 shows the extent of flooding during a defended 1 in 100-year event.

Figure C-8 shows the extent of flooding during a defended 1 in 100-year event divided in three levels of risk High-High > 0.5m depth of flood -water, High-Medium 0.2m – 0.5m depth and High-Low < 0.2m depth..

Figure C-9 shows the extent of flooding during a defended 1 in 10-year event including an additional 20% flow to account for climate change.

Figure C-10 shows the extent of flooding during an undefended 1 in 100-year event (Zone 3) and the additional flooding during a 1 in 1000-year event (Zone 2)

Figure C-11 shows the extent of flooding during a defended 1 in 100-year event with an additional 20% flow added to account for climate change (see Section 2.5).

It can be seen from the Figures that when the Leigh Barrier is operating only a small part of this land is within Flood Zone 3.

Development should avoid interference with floodplain flows or compromising future river management options.

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Figure 6.1: Flood Extent on 13 October 2000 (looking north-west from east Tonbridge)

Figure 6.2: Flood Extent on 13 October 2000 (looking north-west)

7 Aylesford

The town of Aylesford is built on the banks of the River Medway. The town is situated on the border between the main flooding influences coming from tidal and fluvial conditions. The area has a history of flooding with the most notable flooding occurring in 1953.

The area being considered for regeneration is to the west of Aylesford Village on the south side of the river in an area known as Mill Hall. The previous flood extent outlines from 1D hydraulic modelling (shown in **Figure D-3**) indicate that flooding occurs of both banks of the River Medway. The Figure shows the predicted extent of flooding during a 1 in 200-year event (Flood Zone 3) and the additional area which would be flooded during a 1 in 1000-year event (Flood Zone 2), when using results from the 1D hydraulic model. This modelling does not take account of flood defences along the river.

The results from the 2D modelling, which takes account of flood defences along the river, (**Figure D-1**) shows that flood defences protects a significant area previously shown to be at flood risk. **Figure D-1** shows the 1 in 200-year outline from the 2D model and the additional areas flooded during a 1 in 1000-year event. **Figure D-2** shows the 1 in 200 year outline with an additional 20% flow to account for climate change.

Flood defences in the area were surveyed using Low-Level LiDAR techniques to gather dense spot height data along defences in the area. These data produced a detailed data set showing the height of flood defences at roughly 2m intervals. Field visits were used in areas were the path of the flood defences were uncertain.

8 Limitations

The use of computer models to simulate natural systems is well established and almost universally accepted. However, natural systems are variable and predicting the exact depth and extent of flooding can be uncertain.

The accuracy of modelling outputs is dependent on the quality of modelling inputs. Some of the data used has been dated by new development in the town. Checks have been carried out. We are reassured that none of the changes are sufficient to cause excessive error in our estimations.

A range of assumptions have been made in regard to rainfall, operation of flood defences, the condition of the river system and land levels through the town centre. Thus the model will only predict the outcome of a given set of assumptions. A conservative approach has been used and, where uncertainty exists, a precautionary principle has been applied.

Models are quality assured by carrying out checks of model outputs against known flood events. Modelled flood depths and extents are compared with data from recorded flood events. When a difference between modelled and recorded flooding is found, analysis is carried out so that the model may be adjusted to more closely represent the natural system.

The findings of the study represent the best possible estimate of the extent and depth of flooding given the constraints of time and cost. It is possible that more detailed modelling, or improvements to the input data could improve accuracy. A summary of some of the limitations of the modelling can be found in the Appendix E.

9 Flood Risk Management, Mitigation and Enhancement Measures

9.1 Introduction

Some of the potential development sites identified by T&MBC are at flood risk during a 1 in 100-year event, especially within the centre of Tonbridge - without defences almost all of central Tonbridge would be within Zone 3. While it is recognised that risk avoidance is the preferred way to manage risk, the reallocation of development from high risk sites to lower risk areas is unlikely to address a range of sustainable development objectives because of the lack of alternative development sites to deliver the regeneration of Tonbridge town centre.

Where development is required to take place in a high flood risk area, the next step in the PPG 25 sequential test is to develop mitigation measures that further reduce the residual flood risk. This is the major task for Tonbridge; to recognise the scope of flood risk and to bring forward imaginative and sustainable techniques to manage and mitigate flood risk.

The EA and T&MBC will be working in partnership ensuring that when they are consulted on individual development proposals mitigation measures are incorporated that reduce flood risk as far as possible whilst facilitating quality design. This Chapter outlines generic mitigation measures; these measures are not mutually exclusive and are more effective when used in combination.

9.2 Aims of Management, Mitigation and Enhancement Measures

The major risks of flooding, within the areas covered by this report, come from fluvial flood inundation, either through overtopping or breaching of the existing defences. Measures to manage and mitigate this flood risk need to therefore aim to achieve the following, where appropriate:

- Designing development that does not remove or reduce existing floodplain storage, and, where appropriate, provides for additional flood storage;
- Planning the detailed location and arrangement of development to reduce flood impact;
- Minimising the number of properties and key infrastructure that might be inundated as a result of flooding;
- Improvements to reduce the likelihood and impact of overtopping or breaching of the flood defences;
- Improving water conveyance through the river system.
- Connecting flood warning and emergency procedures so that a planned evacuation of the more vulnerable areas can be effected. Access by emergency services to individual developments should, nevertheless be maintained.

Mitigation measures should have no adverse affect on other properties. For example, a mitigation scheme that reduces floodplain storage or obstructs flow is not desirable if it increases the likelihood and/or severity of flooding elsewhere. Mitigation should seek to reverse this effect wherever possible.

Proposed mitigation measures should also be sustainable in the long-term. This requires that any flood defence or mitigation measure accompanying development proposals be subject to an appraisal that addresses sustainability. This requires measures that employ good standards of urban design with high flood resilience; that enhance local recreation and amenity; which protect ecology, safeguard water resources and utilise Sustainable Drainage Systems (SuDS) (where appropriate – the Environment Agency can advise on this).

It is important to recognise that it is not always possible to eliminate residual flood risk, only reduce and manage it to acceptable levels.

9.2.1 Generic Risk Management Measures

There are a number of generic flood risk mitigation measures that could be considered in order to reduce flood risk to specific developments. These are described below. It is again noted that these measures are not mutually exclusive and are more effective when used in combination. It is important, however, that the specific use of any of these mitigation measures is considered in detail through a detailed flood risk assessment, particularly to assess whether such mitigation measures may increase the likelihood and/or severity of flooding elsewhere in the catchment. Developers are advised to discuss with T&MBC and the EA the particular measures that would be appropriate to their particular site and the proposal they have made.

(i) Provision of Appropriate Flood Defences

Within the T&MBC area, an appropriate flood defence would be represented by a primary wall or embankment with a minimum standard plus freeboard and accounting for climate change to 2056. For fluvial defences the standard is 1 in 100-year level and for coastal defences 1 in 200-year level . The current level of defences through the centre of Tonbridge is closer to the current 1 in 100 year level without freeboard.

It needs to be recognised that the construction of new flood defences in a fluvial environment tends to reduce the storage potential of a floodplain which in turn may lead to an adverse effect on other properties. For this reason new defences may require the parallel provision of compensatory flood storage.

(ii) Reduce the Structural Fragility of Existing Defences

Determining how a defence may fail is complex. However, in general terms it is considered that a failure of an earth embankment, either by breaching or overtopping, results in a greater flood flow than a hard embankment due to scouring out of the material forming the defence during breaching. As a result it is considered that traditional earth embankments have a higher inherent residual risk than hard embankments.

Reducing the structural fragility of embankments by adopting hard engineering solutions would therefore lower the residual flood risk, however, such decisions would need to be considered with regard to the potentially negative aesthetic value of such a defence, in addition to the economic implications of such work.

(iii) Land Raising

The use of land raising as a mitigation measure must be considered on its merits depending on the local conditions of each development. As with the building or extending of flood defences, land raising reduces the amount of available floodplain storage and could increase the depth and/or extent of flooding elsewhere. However, in some cases the potentially negative affects of land raising could be countered by providing compensating areas which could accept flood water to a greater depth without suffering greater consequences, for example, public open space.

Where there is existing land contamination on brownfield sites it may be necessary to cap the area prior to redevelopment. This type of filling will often have a similar localised impact on residual flood risk as land raising and the impacts should be investigated in the same way. Where adverse impacts from caping are identified, alternative options for remediating land contamination should be considered.

Land raising could be considered where it has the overall effect of reducing residual flood risk in the wider catchment. Building up low-lying land immediately adjacent to flood defences could lessen the likelihood and/or scour depth (and therefore inflow volume) of a defence breach. The overall reduction in residual flood risk of the catchment may outweigh any loss of floodplain.

Land raising could also be considered in areas that are hydraulically independent from the rest of the catchment. For example, small areas of land that are bounded by road embankments, rail embankments, watercourses or flood walls could be raised to reduce local flood risk without increasing flood risk elsewhere. The whole area, however, may require infilling in order to maintain parity of flood risk across the community.

On a smaller scale, some areas of land raising may be possible as part of specific developments (e.g. adjacent to existing raised areas) where compensatory flood storage is provided and flow conveyance is not affected (e.g. by using open spaces effectively).

The impact of reducing flood storage could also extend outside of the T&MBC area, affecting upstream and downstream areas. This requires a significantly wider appreciation of the risks associated with land raising, particularly in terms of strategies to mitigate the effects of climate change. Land raising should therefore be used with caution by assessing the potential wider impact it could have for other adjacent low-lying areas. Land raising has been used extensively as a mitigation option in the recent past, however other options which maintain the available flood storage and allow the transit of flood water to low-lying land where the consequences of flooding are lower should be considered in preference to this option.

(iv) Non-Habitable Ground Floor

The lowest-lying areas of land within the T&MBC area are likely to experience the greatest depths of flooding, and consideration should be given to land uses other than residential in the areas with the greatest risk.

Designing dwellings with a non-habitable ground floor is one mitigation option for residential development in low-lying areas. The ground floor could be used for flood compatible uses such as car parking, flood resilient storage, public open space, etc. However, great care must be taken in the urban design of areas with non-habitable ground floors to avoid adverse perceptions of safety and security by the local residents. There are also potential conflicts with the requirements of the Disability Discrimination Act.

The main issue with this solution is that containment at first floor level for long periods of time without power is unlikely to be feasible, therefore this solution would only work where evacuation to high ground is obvious and does not involve moving through deep water.

Safe access and egress to higher land is key to the successful mitigation of flood risk through this measure.

(v) Secondary Defences – Flood Storage, Flood Bunds and Drainage Improvements

Secondary defences can consist of a variety of structural or design features that reduce the risk or consequences of flooding in an embayment. An effective secondary defence system will integrate some or all of the following elements:

- 'Green grid' of flood storage and detention basins – open space and recreational areas that are normally dry but are designed (and located) to preferentially flood ahead of residential areas;
- Sustainable Urban Drainage systems as ways of reducing the volume and speed of run off;
- Bunds – low level raised banks that are designed to protect sensitive areas by excluding or delaying floodwaters. These can also be used to direct flood flows to detention basins;
- Canals, lakes and water features – networks of water features and canals that are designed with freeboard to provide additional flood storage. Canals can also act as efficient flow paths to direct floodwaters into storage areas.

Secondary defences have the benefit of delaying the inundation of residential areas and slowing the velocity of floodwaters. The extra warning time and reduction in flow velocity would reduce the risk to life. The overall effectiveness of secondary defences, however, will depend on location and magnitude of the flood inflows and the design and storage capacity of the system, as well as the maintenance of these systems.

The design of such mitigation measures must ensure that they do not increase the risk of flooding or the speed of inundation in localised areas elsewhere in the catchment, unless these areas are specifically dedicated and safeguarded for this purpose.

The main draw back of secondary defences is their requirement for maintenance and inspection particularly because they do not form part of the main flood defence system. There is a greater likelihood of their function to be forgotten after their construction with a greater risk of the flood defence failing to operate as designed.

(vi) Culvert Opening / Increasing Conveyance Through Town

There is potential for the culverted section of Botany stream to be returned to open channel in association with new development. This would bring the benefit of additional capacity in the system and reduce the risk of blockages. This option could increase conveyance through Tonbridge, potentially reducing the risk of flooding to sites both north and south of Gas Works Stream. This option would be a strategic flood management option rather than a site specific mitigation option. The precise benefits of these measures would only be understood after testing within a hydraulic model. This work will be commenced as a matter of priority by the EA, in conjunction with T&MBC, as a continuation of this study.

(vii) Flood Resilient Design

New development should be designed using flood-proofing measures to ensure that it is sustainable in the longer term. Details of appropriate flood proofing measures are outlined in the reports 'Design Guidance on Flood Damage to Buildings'[7] and 'Flood Resilient homes' [8] and include measures such as:

- Raising floor levels;
- Flood proofing of walls and floors through replacement of timber floors with concrete and replacement of gypsum plaster with more water-resistant material, such as lime plaster or cement render;
- Replacing chipboard/MDF kitchen and bathroom units with waterproof alternatives;
- Raising service meters, boiler and electrical circuitry;
- Installing one-way valves into drainage pipes;
- Flood proofing gardens.

(viii) Safe Access and Egress

New development within a floodplain should be designed to ensure safe access during flood events. Such routes should ideally be dry in the event of the design flood. The need for an individual to enter flood water, as part of a modern development, should be avoided. Access routes should be safe to use at the volition of the occupier and not dependent upon the intervention of the emergency services or others. The minimum access requirement is that the route should be safely accessible to pedestrians.

(ix) Flood Warning and Emergency Procedures

Flood warning and emergency procedures will form an important part of the management of residual risk. Development of these procedures will require a rigorous analysis of multiple breach locations and events. The type of elements that should be covered include:

- Responsibilities of authorities
- Procedures to repair breaches and to limit overtopping
- Evacuation routes and dry flood refuges
- Community education
- Flood warning dissemination
- Plans for vulnerable community sites (hospitals, retirement homes, nurseries etc.)
- Plans for vulnerable infrastructure (tunnels, etc.)
- Flood information packs for new development - contact the EA.

Local authorities in coordination with the Environment Agency, emergency services and NHS bodies are responsible for developing and updating emergency plans as part of the 2004 Civil Contingency Act.

[7] Building Research Establishment Scottish Laboratory, 1996

[8] Association of British Insurers, April 2004

The EA is already involved in the coordination and issuing of flood warning. Flood Warnings are issued from the Environment Agency Area Offices by contacting the main stakeholders including blue light services.

Studies are in progress to address emergency planning issues. The Environment Agency is also sponsoring a major research and development initiative, the “Flood Forecasting and Warning Research Programme.” As flood warning is a national issue, it has been recommended that the National Flood Warning Centre should manage the process to ensure consistent policy is adopted using best practice guidelines.

In a drive to make flood warning more accessible to the general public the Environment Agency has invested in an upgrade of Flood Line Direct which uses the latest technology such as e-mails and text messaging.

10 Review and Updates

The SFRA for Tonbridge and Malling is an evolving document that will need to be reviewed and updated, when appropriate, in the light of the following: revised and/or new spatial guidance; changes to modelling software; updated survey work; changes to topography; changes to watercourses; and/or changes to defences.

The EA and T&MBC will work in partnership to ensure that the SFRA responds to the changes identified above and is kept current, thereby maintaining its value as a document to inform the formulation, review and implementation of the LDF.