# Marden Surface Water Management Plan

Final Report

February 2017

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# Revision History

| Revision Ref / Date Issued | Amendments | Issued to |
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| August 2016 / v1 | | Max Tant, Kent County Council |
| September 2016 / v2 | Address comments from Kent County Council | Marden SWMP project partners |
| February 2017 / v3 | Address comments from the project partners | Max Tant, Kent County Council |

# Contract

This report describes work commissioned by Max Tant, on behalf of Kent County Council. Kent County Council's representative for the contract was Max Tant. Jennifer Hill and Christopher Matthias of JBA Consulting carried out this work.

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# Purpose

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# Acknowledgements

JBA would like to thank Kent County Council, Maidstone Borough Council, Marden Parish Council, Southern Water, the Environment Agency and the Medway IDB for their contributions throughout the project.

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# Executive Summary

A Stage 1 Surface Water Management Plan (SWMP) for Maidstone was commissioned after the Preliminary Flood Risk Assessment (PFRA) for Kent found that Maidstone was the settlement most at risk of surface water flooding settlement in the county. The Stage 1 SWMP for the Maidstone District found a history of flooding in the village of Marden. A common source of the flooding was found to be highway flooding from exceeded drains and sewer flooding.

This Stage 2 SWMP, focussing specifically on Marden, was commissioned in 2014 as a detailed assessment of local flood risk, following Defra (2010) guidance. The aim of this study was to provide a detailed understanding of the causes and consequences of surface water flooding and to test the benefits and costs of mitigation measures.

Understanding the causes of surface water flooding was achieved by;

- updating the flood history to include recent incidents and understanding the source and pathway of the flooding; and
- creating an integrated model of flood risk and analysing the results to understand the flood mechanisms.

Understanding the consequence of the flooding was achieved by;

- understanding the receptor of recorded flood incidents;
- counting the dwellings and critical infrastructure predicted to flood; and
- calculating the economic damages of predicted flooding to dwellings and critical infrastructure.

Hotspots were defined as areas with repeated flood history or predicted risk from the Integrated Urban Drainage Model and the updated Flood Map for Surface Water. The hotspot areas in Marden were: The Cockpit, Howland Road, Goudhurst Road and the Wheelbarrow Industrial Estate. The cost of flooding at each of these hotspots was assessed using the model results and the Multi-coloured Manual of flooding damage curves.

At each hotspot, a long list of potential flood risk mitigation measures was drawn up. The feasibility of these options was assessed on a site visit and against known restrictions to develop a short list of options. The effectiveness of each option was tested in the hydraulic model. These included and attenuation basin on the Cockpit estate and drainage ditches at Howland Road and the Wheelbarrow Estate.

The revised cost of flooding was then calculated using the options model results and the Multi-coloured Manual of flooding damage curves. The benefit of the option was then contrasted with the estimated cost of construction using Cost-Benefit Analysis. The surface water detention basin at the Cockpit was the strongest option, but none of the options were found to be cost beneficial. Therefore, KCC would not be able to secure funding for these proposed scheme via the Flood Grant in Aid process.

As a result, the action plan focuses on low cost measures to manage the risk such as maximising existing drainage features with regular cleansing, and improving flood resilience with use of Property Level Protection.

There is significant development planned for Marden. There is a risk than inappropriate drainage design could exacerbate the existing flooding issue. Marden Neighbourhood Plan is developing policies to enforce appropriate drainage design considering these local restrictions. Therefore, the development could provide an opportunity to help manage local flood risk. For example, development on Howland Road should consider the drainage design at master planning stage and if a drainage ditch and pond system is preferred, this could formalise the existing surface water flow path at the south of the site.

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# Abbreviations

AEP ................................ Annual Exceedance Probability
CCTV ............................. Close Circuit Television
CEP ................................ Communication and Engagement Plan
DA .................................. Drainage Area
DFGiA ............................. Defra Flood Grant in Aid
DTM ............................... Digital Terrain Model
IDB ................................. Internal Drainage Board
IUD ................................. Integrated Urban Drainage
JBA ................................. Jeremy Benn Associates
KCC ................................ Kent County Council
LLFA .............................. Lead Local Flood Authority
MBC ............................... Maidstone Borough Council
mAOD ............................ metres Above Ordnance Datum
NPPF ............................. National Planning Policy Framework
NRD ............................... National Receptors Database
PLP ................................ Property Level Protection
RMA ............................... Risk Management Authority
SFRA ............................. Strategic Flood Risk Assessment
SHLAA ........................... Strategic Housing Land Availability Assessment
SuDS .............................. Sustainable Drainage Systems
SWMP ............................ Surface Water Management Plan
uFMfSW ......................... updated Flood Map for Surface Water

# 1 Introduction

This surface water management plan (SWMP) has been undertaken to explore the local flood risks in the Parish of Marden. It has been prepared by a partnership of Kent County Council, the Environment Agency, Maidstone Borough Council, Upper Medway Internal Drainage Board (IDB), Southern Water and Marden Parish Council.

## 1.1 What is a Surface Water Management Plan

A Surface Water Management Plan (SWMP) is a study to understand the flood risks that arises from local flooding, which is defined by the Flood and Water Management Act 2010 as flooding from risk from surface runoff, groundwater, and ordinary watercourses.

SWMPs are led by a partnership of flood risk management authorities who have responsibilities for aspects of local flooding, including the County Council, Local Authority, Sewerage Undertaker and other relevant authorities.

The purpose of a SWMP is to identify what the local flood risk issues are, what options there may be to prevent them or the damage they cause and who should take these options forward. This is presented in an Action Plan that the partners agree.

Kent County Council (KCC) often takes a two stage approach to SWMPs. Initially, a Stage 1 SWMP is undertaken which collects all the available flood risk and flood history data in the catchment. Where this process identifies a flood prone area a Stage 2 SWMP can be required to make a more detailed assessment of flood risk and focus the resulting action plan of flood mitigation measures.

## 1.2 Stage 1 SWMP: key findings

Kent County Council in partnership with the Environment Agency, Maidstone Borough Council, Upper Medway Internal Drainage Board (IDB) and Southern Water prepared the Stage 1 Maidstone SWMP to investigate the local flood risks to the Maidstone borough, published in 2014.

The Maidstone SWMP study area was subdivided into Drainage Areas to allow more in depth analysis. A list of all the drainage areas in the Maidstone SWMP is available in Table 1-1.

Table 1-1 Maidstone Stage 1 SWMP Drainage Areas (DA)

| Drainage Area | Location |
|---|---|
| DA01 | Maidstone Rural North |
| DA02 | Maidstone Rural Mid |
| DA03 | Maidstone Rural West |
| DA04 | Maidstone Rural East |

The area of the Marden Surface Water Management Plan falls within DA04, Maidstone Rural East. The Stage 1 SWMP stated that there were numerous flooding issues identified in Marden, the perceived causes recorded included poor drainage, blocked drains and local topography. Therefore, one of the conclusions of the study was that an integrated catchment model was needed for Marden.

## 1.3 Stage 2 SWMP: drivers

The preparation of a Stage 2 SWMP was driven in response to the following primary considerations:

- The need to manage local flood risk as a consequence of assessments performed under the Flood Risk Regulations, 2009 or the Flood and Water Management Act 2010;
- The need to inform spatial planning and development control, develop a strategy for flood risk management, and provide evidence that future new development can be implemented and local flood risk safely managed; and
- The need to build on the understanding of high risk areas highlighted within the Stage 1 SWMP and to develop feasible options for improving local flood risk within known hot spot areas.

## 1.4 Study objectives

The objectives of the Marden Stage 2 SWMP as set out in the scope of work are:

1. The establishment of a local partnership as a steering group;
2. The collation and mapping of a comprehensive flood history for all relevant local flood risk sources which may include collecting data from residents of Marden;
3. The preparation of source pathway receptor models for all the risks and sources that are identified;
4. The preparation of a hydrodynamic flood model
5. The predicted flooding, including depth, velocity and hazard to people from the 1 in 2, 5, 20, 30, 75, 100, 100 +CC and 1000 events;
6. Determine the areas at risk of flooding;
7. Identification of the causes of flooding and/or constraints to drainage;
8. Estimate the economic impact of flooding to the Marden and to assess mitigation options for the flood risk identified;
9. Identify potential mitigation options for the flood risks identified;
10. Identification of opportunities to deliver flood risk management benefits through local planning documents, including neighbourhood plans;
11. Set out a clear plan for further work that may be necessary to manage or better understand the risks identified.

## 1.5 Study area

The Stage 2 SWMP focuses on the village of Marden within the Maidstone Borough. This area includes the entire parish and is shown in Figure 1-1 and spans north to Chainhurst and south to Winchet Hill.

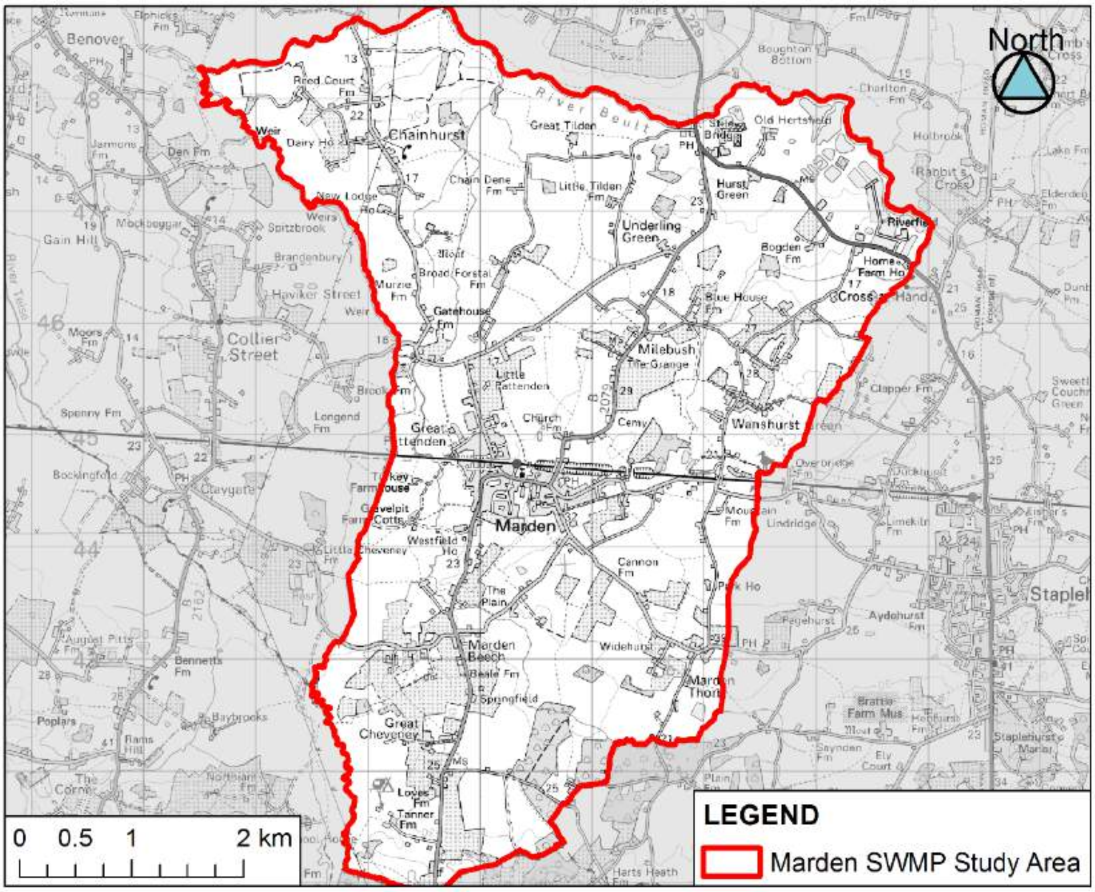


Figure 1-1 Marden SWMP study area

# 2 Partnership and Communications

## 2.1 Partnership approach

Surface water cannot be managed by a single authority, organisation or partner; all the key organisations and decision-makers must work together to plan and act to manage surface water across Marden. Many organisations have rights and responsibilities for management of surface water. Although Kent County Council commissioned this project, the key partners have been consulted at appropriate stages in the study. Working in partnership encourages co-operation between different agencies and enables all parties to make informed decisions and agree the most cost effective way of managing surface water flood risk across Marden in the long term. The partnership process is also designed to encourage the development of innovative solutions and practices and improve understanding of surface water flooding.

## 2.2 Partners

Partners are defined as organisations with responsibility for the decision or actions that need to be taken to manage surface water flooding. The partners involved in this project are listed in

Table 2-1 Partners involved in the Marden SWMP

| Partner Organisation | Representative(s) |
|---|---|
| Kent County Council (Flood Risk Management) | Max Tant<br>Joe Williamson |
| Kent County Council (Highways) | Adam Murdin |
| Maidstone Borough Council (Drainage)<br>Maidstone Borough Council (Planning) | Bill Axel<br>Chris Berry |
| Southern Water Utilities Ltd | Mike Tomlinson |
| Environment Agency | Peter Waring |
| Medway Internal Drainage Board | Michael Watson |
| Marden Parish Council | Andrew Turner |

The project partners have supplied the data to inform this SWMP and have been attributed as action owners in the SWMP action plan. Marden Parish Council have been involved throughout the preparation of this SWMP. The Parish Council have supported the production of the SWMP by passing on their detailed local knowledge of flood incidents that have occurred in Marden and explaining the impact of flooding on the community.

In addition to the above, the Maidstone Borough Council (MBC) Planning department was also involved in the SWMP. As the authority responsible for setting local planning policy, it sets the development strategy for the area which will have a direct impact on how surface water is managed in new developments and redevelopments in the study area.

## 2.3 The Communication and Engagement Plan

A Communications and Engagement Plan (CEP) was developed and maintained to;

- Illustrate internally and externally the importance of communicating honestly and transparently with our delivery partners, stakeholders and communities;
- Support the project team in spending time and resources wisely, informing and involving the right people about the right things, at the right time; and
- Act as an overarching umbrella plan which ensures co-ordination between stakeholder engagement activities, media communications, internal/external communications, external funding and stakeholder support, other consultations.

## 2.4 Partnership meetings

Meetings have been held at key points throughout the project to consult the project partners and incorporate the knowledge of local issues.

The first project steering group focused on knowledge capture. The recorded flood incident data provided by the partners was presented and early identification of flooding hotspots were discussed. The project partners also shared information on their assets which could impact flood risk and any proposed schemes. This meeting was also used to develop the survey needs and modelling strategy. Here it was identified which drainage systems would be included in the model and what information would be required to support this. Key outcomes from the first steering group meeting were:

- Understanding the KCC highways had undertaken remedial works on Stanley Road and South Road
- Planned survey of the highway drainage assets by KCC for inclusion in the model
- Flooding of Plain Road can cut off access to Marden, which can only be avoided via a long diversion.

The second project steering group meeting focused on review of the draft model results. The hydrological analysis and model build process were explained and the draft outputs shared with the partners as animations and maximum depth results. Key outcomes from the second steering group meeting were:

- Flood extents behind Goudhurst Road match well with observed in 2013/2014
- Flood risk behind Howland Road is expected
- Flood risk to the Wheelbarrow Park Estate underestimates observed.

The third and final project steering group meeting focused on review of the options modelling, cost benefits analysis and discussed the way forward for Marden. Key outcomes from the third steering group meeting were:

- The cost estimates appeared to underestimate the cost of construction based on experience in Kent, leading to the application of 'optimism bias' which is reasonable for a schemes at this outline stage
- The conclusion that no capital scheme would be cost effective in Marden because of the low benefits compared to high costs

In addition to full partnership meetings, two meetings have been undertaken between JBA, KCC and Southern Water

# 3 Risk Assessment

The risk assessment chapter of this report outlines the approach taken to assess the flood risk and summarises the results of the assessment.

## 3.1 Levels of assessment

The Maidstone Stage 1 SWMP highlighted the drainage area covering Marden as having a significant history of flooding, particularly on the highways. Therefore, in line with the Defra guidance[1], a detailed assessment has been undertaken for this Stage 2 SWMP. This level of assessment aims to provide a detailed understanding of the causes and consequences of surface water flooding, and to test the benefits and costs of mitigation measures. This will be achieved through the modelling of surface and sub-surface drainage systems. The results of the detailed analyses have then been used to prepare an action plan.

The risk assessment carried out used the Source > Pathway > Receptor approach:

- Source - the origin of flood water
- Pathway - a route or means by which a receptor can be affected by flooding
- Receptor - something that can be adversely affected by flooding

Having applied the Source-Pathway-Receptor model it is possible mitigate the flood risk by addressing the source (often very difficult), block or alter the pathway and even remove the receptor e.g. steer development away from sources and pathways of flooding.

## 3.2 Catchment characteristics

Both the natural and built environment impacts the risk of flooding from local sources. This section characterises the catchment including the fluvial network, geology and drainage network from urban areas.

### 3.2.1 Physical features

The SWMP study area contains a number of watercourses, the River Beult forms the northern boundary of the parish and the River Teise or Lesser Teise forms the western boundary of the Parish. These watercourses are classified as Main River and fall under the jurisdiction of the Environment Agency.

In addition to Main Rivers, there are a large number of Ordinary Watercourses in the surrounding area, some of which join the River Beult and Lesser Teise. Some of these Ordinary Watercourses are within the Upper Medway IDB district. The IDB adopt and maintain some watercourses in their district. Other ordinary watercourses are the responsibility of riparian owners.

The watercourses within the Marden SWMP study area are shown in Figure 3-1. Main Rivers are shown in dark blue whereas the Ordinary Watercourses are in light blue and Internal Drainage Board (IDB) drains are light and dark blue hatched.

[1] Defra (2010) Surface Water Management Plan Technical Guidance. Defra: London

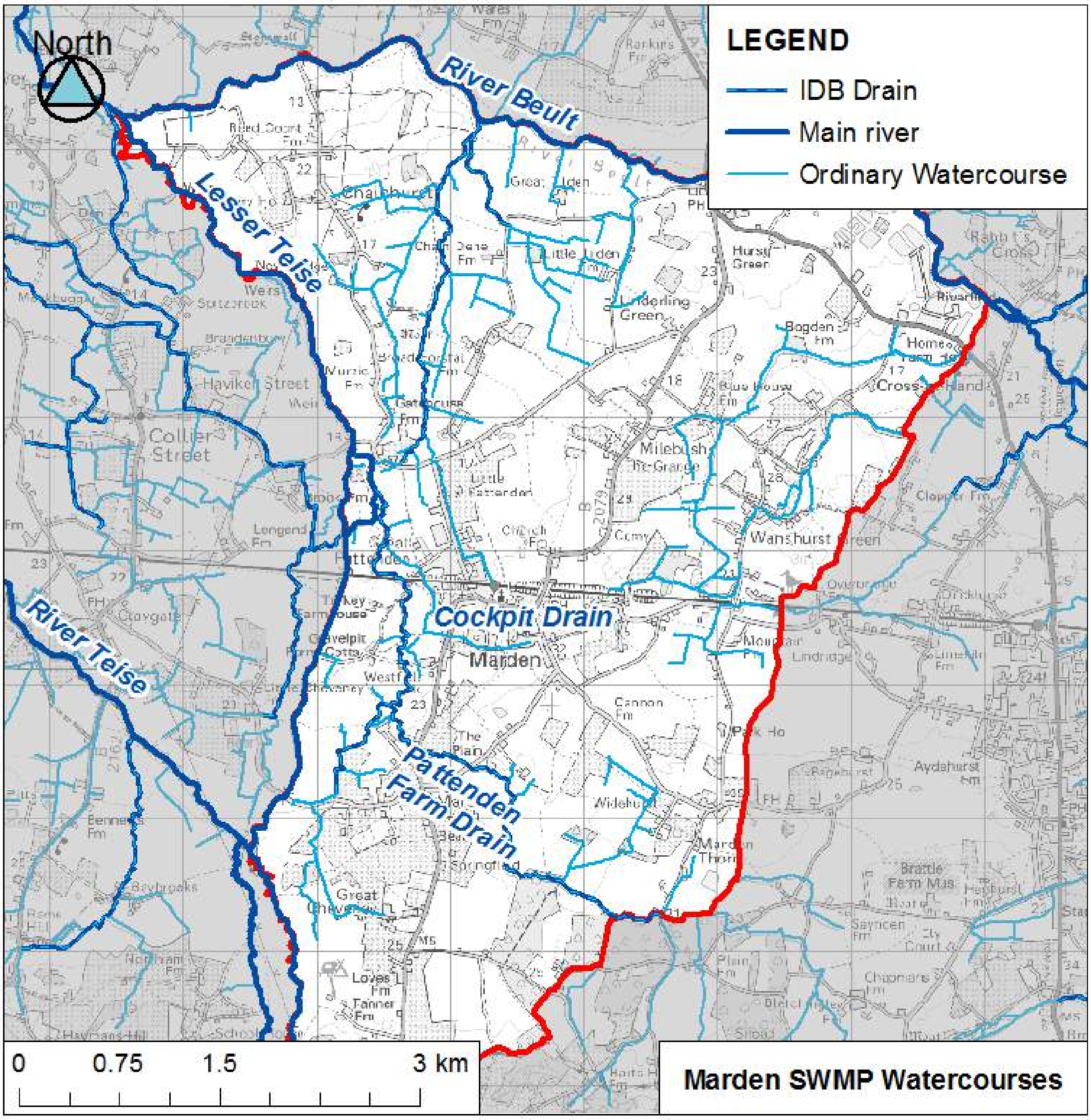




Figure 3-1: Watercourses in the Parish of Marden

Marden is a predominately underlain by the Weald Clay formation which is spatially variable containing predominantly mudstones and siltstones with intermittent limestones. In the south of the SWMP study area the bedrock geology changes to Wadhurst Clay and Tunbridge Wells Sands formations consisting of sandstones, siltstones, clays, mudstones and limestones. Periodic flood events throughout geological time have facilitated the deposition of alluvium and river terrace superficial deposits, which overlay a proportion of the SWMP study area particularly the eastern part of Marden village. The distribution of bed rock and superficial deposits, in reference to the study area, is shown in Figure 3-2.

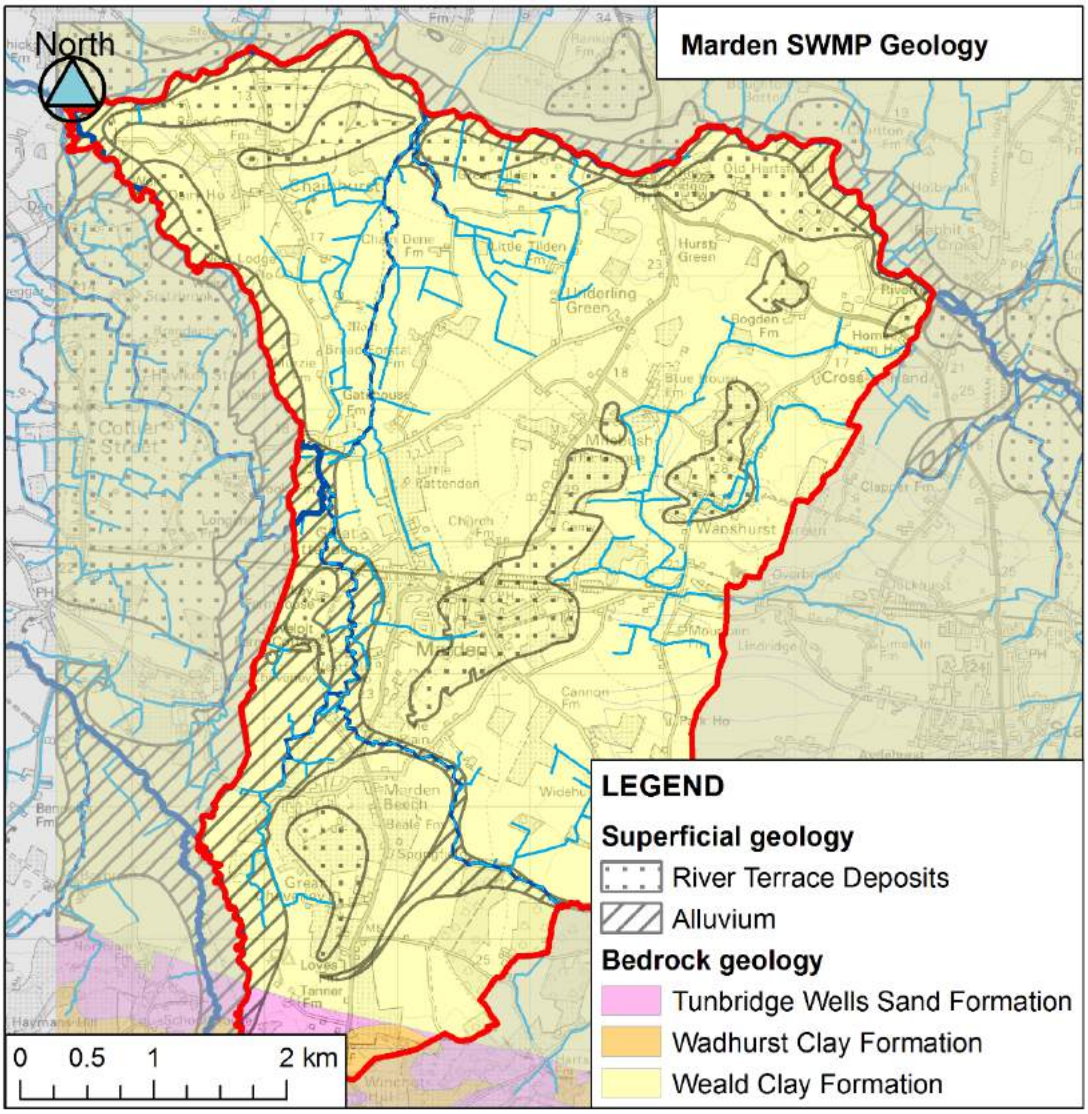




Figure 3-2: Geology in the Parish of Marden

Clays and Mudstones are typically low in permeability and porosity due to their fine grain size but this varies, for example sandstones tend to be more porous and permeable than mudstones. The impermeable bedrock geology is more likely to lead to the generation of surface water runoff, which can be result in pluvial ponding in topographic depressions. However, any fracturing in the geology would act as a conduit for groundwater and also allow for surface water to more quickly infiltrate to the sub-surface in areas.

The superficial geology has more capacity to accept and store surface water runoff as this tends to be less compressed. However, as the infiltration to the bedrock geology below is impeded, there is potential for increasing groundwater flood risk locally.

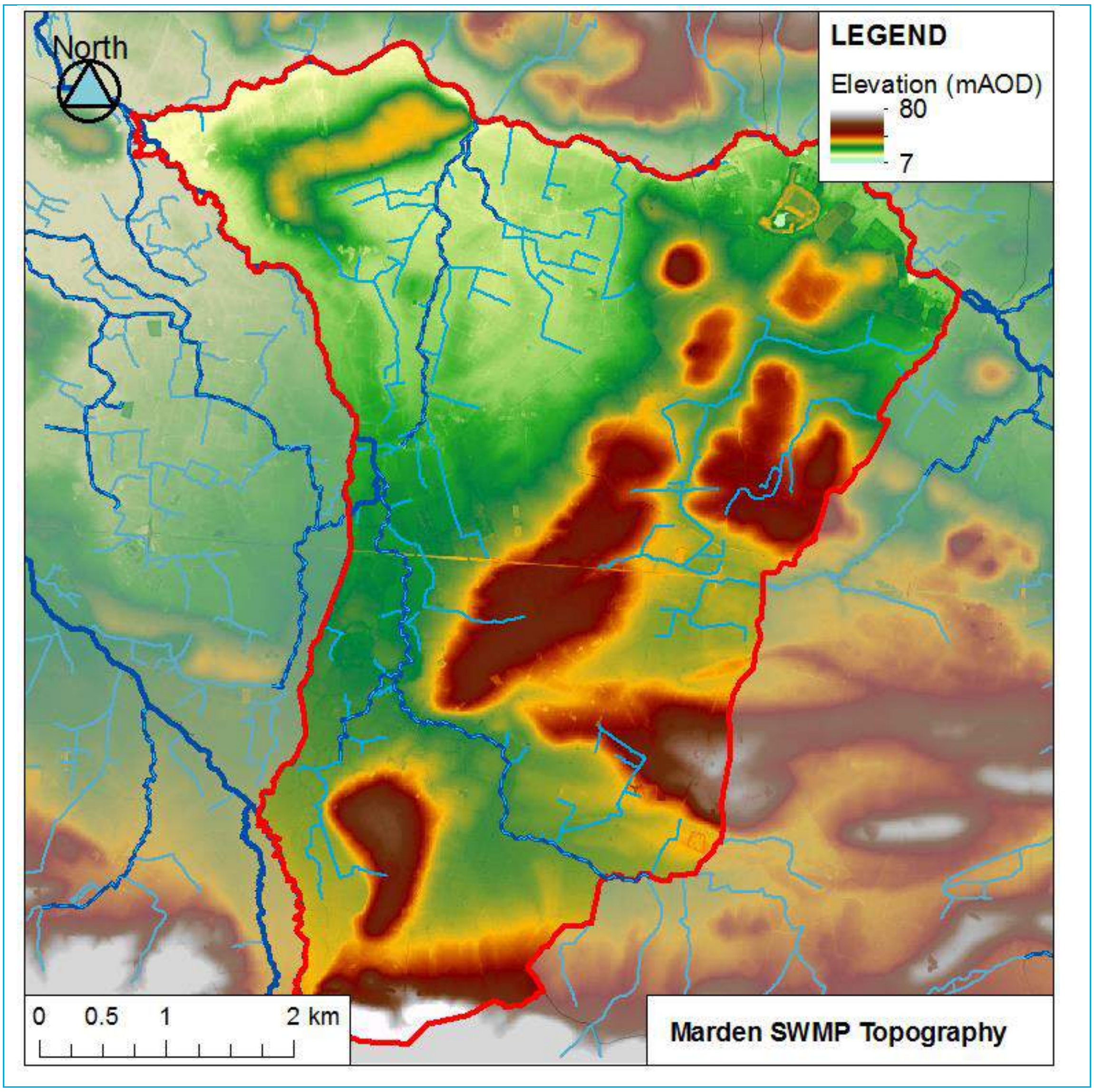


Figure 3-3: Topography in the Parish of Marden

The topography of the parish slopes gently from the highest elevations in the south and east to the lowest elevations in the north west. The village of Marden itself is located on an area of relatively high and flat land around 30 mAOD. The lowest topography follows the Lesser Teise watercourse, around 14 mAOD. A gently sloping topography is not likely to generate a rapid runoff response and instead is more likely to lead to areas of pluvial ponding. Due to the impermeable geology, it is likely that the duration of any surface water ponding could be extended.

### 3.2.2 Land use

Historic mapping has shown that Marden was a linear village following the B2079 in 1898, by 1950 the village had been expanded southward by the military to include a Drill Hall, which was later developed into the Cockpit estate. The Roundel Way development is relatively new (circa 1995) and was previously undeveloped land. The historic maps show a number of ponds within the Parish of Marden. Some of these ponds remain today, but others have been infilled or developed over. Development has occurred at Howland Road, Stanley Road and across the Wheelbarrow Park Estate and infilling has occurred at Meades Close and The Cockpit. No historic watercourses were identified from old maps which are not shown on current day mapping.

Marden village is defined as a Rural Service Centre in Maidstone Borough Council's Core Strategy[2] as it includes facilities and infrastructure used by the surrounding rural communities. The land use is predominately low density residential in the village and agricultural in the parish

[2] Maidstone Core Strategy 2011

as a whole. There is also a small industrial estate located north of the railway line in the village of Marden.

The current land use and potential future growth areas are shown Figure 3-4 which includes aerial photography as it clearly demonstrates predominately rural land use in the parish. The urban areas are generally drained by sewerage, whereas the natural areas are either naturally via infiltration or to the network of drainage ditches.

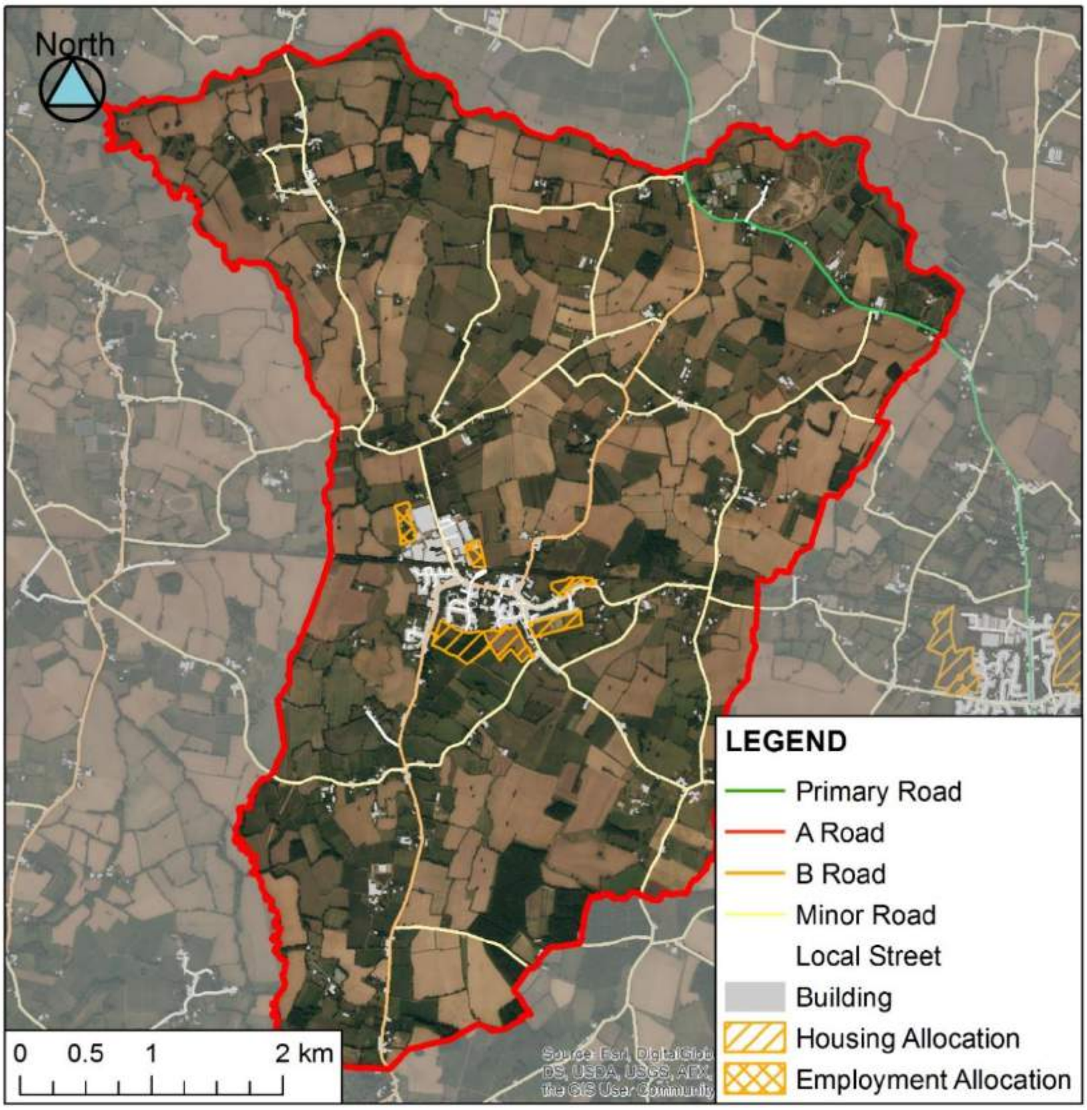




Figure 3-4: Land use in the Parish of Marden

### 3.2.3 Urban drainage

In Marden the sewerage is largely separate, with a sewer network for surface water and another for foul water. However, in the oldest area of the village along the B2079 there is a foul only system with a separate highway drainage system. There is no Impermeable Area Survey (IAS) of this part of Marden to confirm where the roof drainage on the B2079 connects to. It is likely that these were originally designed to drain to soakaway but the Southern Water model shows that that now some roof area is directly connected to foul sewerage. The known drainage assets are mapped in Figure 3-5. The assets have been divided into foul (brown) and surface water (blue) sewers and highway drainage (black).

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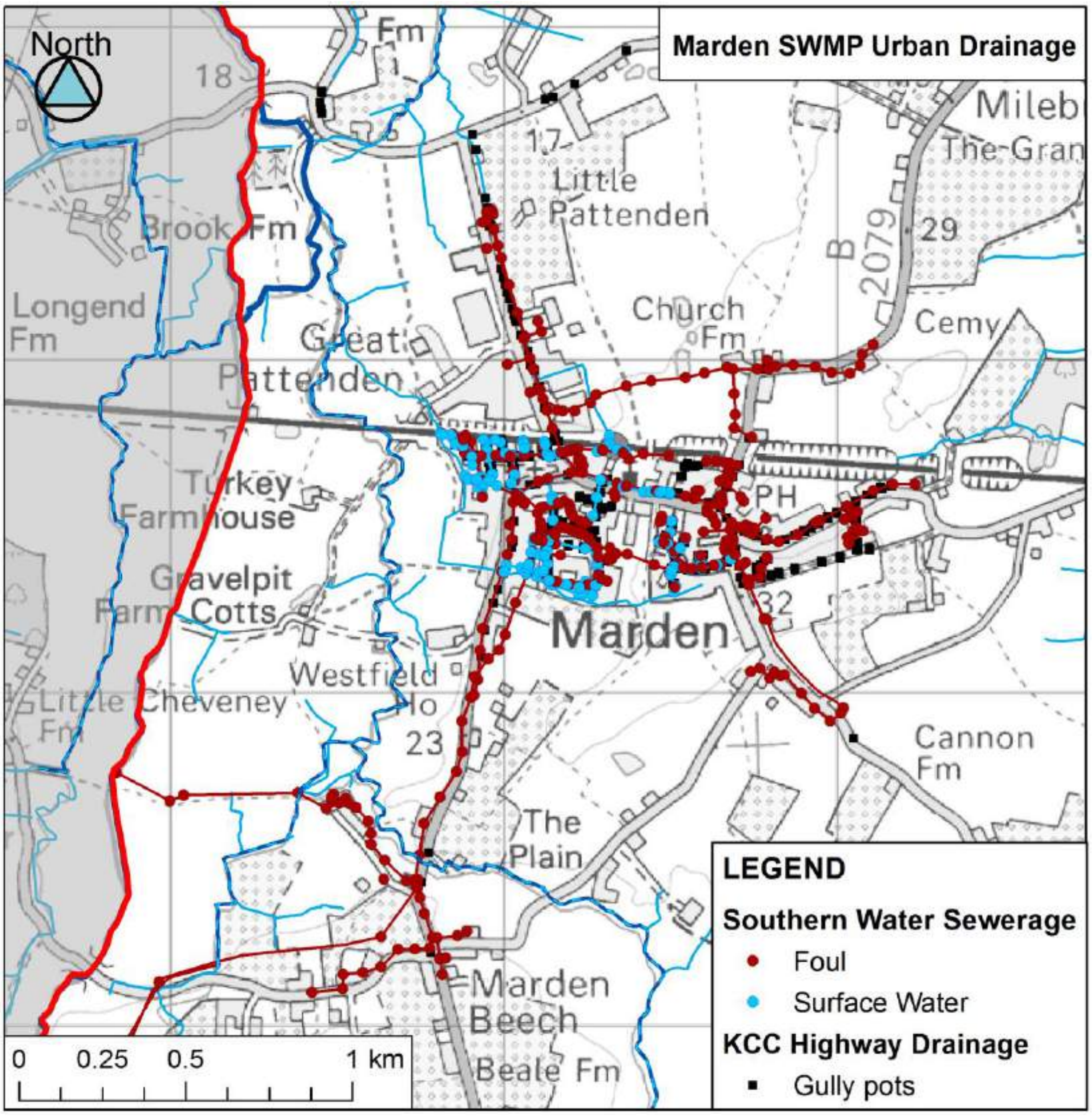


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Figure 3-5 Marden urban drainage network

The public sewerage shown on the map is operated and maintained by Southern Water. In 2011 public sewers were redefined as those which serve more than one property[3].

Highway drainage exists across Marden, operated by Kent County Council. Sections of this drainage network have been surveyed to inform this study. Elsewhere, it has been assumed that the highway gullies drain to a Southern Water surface water sewer when one is available. Otherwise the highways drain to soakaway. This assumption was, where possible, tested and verified when on site.

The Tonbridge to Ashford railway line to the north of the village runs in a cutting at the eastern side of Marden around the Maidstone Road bridge, but at the western side of the village at Pattenden Lane runs on an embankment. From the inspection records provided by Network Rail, four railway culverts conveying watercourses have been identified, as summarised in Table 3-1. The inspection records also summarise the culvert condition at last survey. The last surveys concluded that there were no structural defects to note but that the railway culvert north of Howland Road (reference 320) was heavily sedimented which restricted the forward flow. The survey report recommended clearance of the barrel and approaching ditches.

3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69356/private-sewers-transfer-guidance110928.pdf

Table 3-1: National Rail structures

| Asset Reference | National Grid Reference | Description | Comments | Suggested action |
|---|---|---|---|---|
| 313 | TQ73584480 | Arch bridge | No defects observed which impact flood risk | None |
| 315 | TQ73804479 | Circular culvert | Culvert outlet obscured by vegetation | Clear vegetation |
| 320 | TQ75154470 | Circular culvert | High water level in culvert | Clean out culvert and approach ditches |
| 322 | TQ75824466 | Circular culvert | No defects observed which impact flood risk | None relevant |

## 3.3 Flood history

Flood incident data provided geographical information on where flooding had been recorded. The data provided by the partners was standardised using the Source-Pathway-Receptor model.

### 3.3.1 Source-Pathway-Receptor model

The Source-Pathway-Receptor model is a concept that can provide an understanding of all sources of flood hazard. It is particularly useful in this context as it can be used to generalise the data gathered from numerous sources.

- Source - the origin of flood water
- Pathway - a route or means by which a receptor can be affected by flooding
- Receptor - something that can be adversely affected by flooding

Having applied the Source-Pathway-Receptor model it is possible to mitigate the flood risk by addressing the source (often very difficult), block or alter the pathway and even remove the receptor e.g. steer development away.

### 3.3.2 Historic sources of flooding

The recorded flood history in Marden indicates that the main flood mechanisms operating within the village are: over land flow during intense rainfall (associated in part to drainage blockage) and sewer exceedance during intense and prolonged rainfall.

The Stage 1 SWMP for Maidstone collated data on incidents of historical flooding from each Risk Management Authority. During the Marden SWMP, these flood incident records have been updated to 2014. A summary of flood incident source and location is shown in Figure 3-6.

The majority of the flood incidents recorded within the Marden parish are within the village of Marden itself. The location of these incidents are distributed across the village, but there are a number of issues reported clustered in some locations. It is likely that the infrastructure related to the flooding incidents have subsequently been cleaned or replaced in most cases.

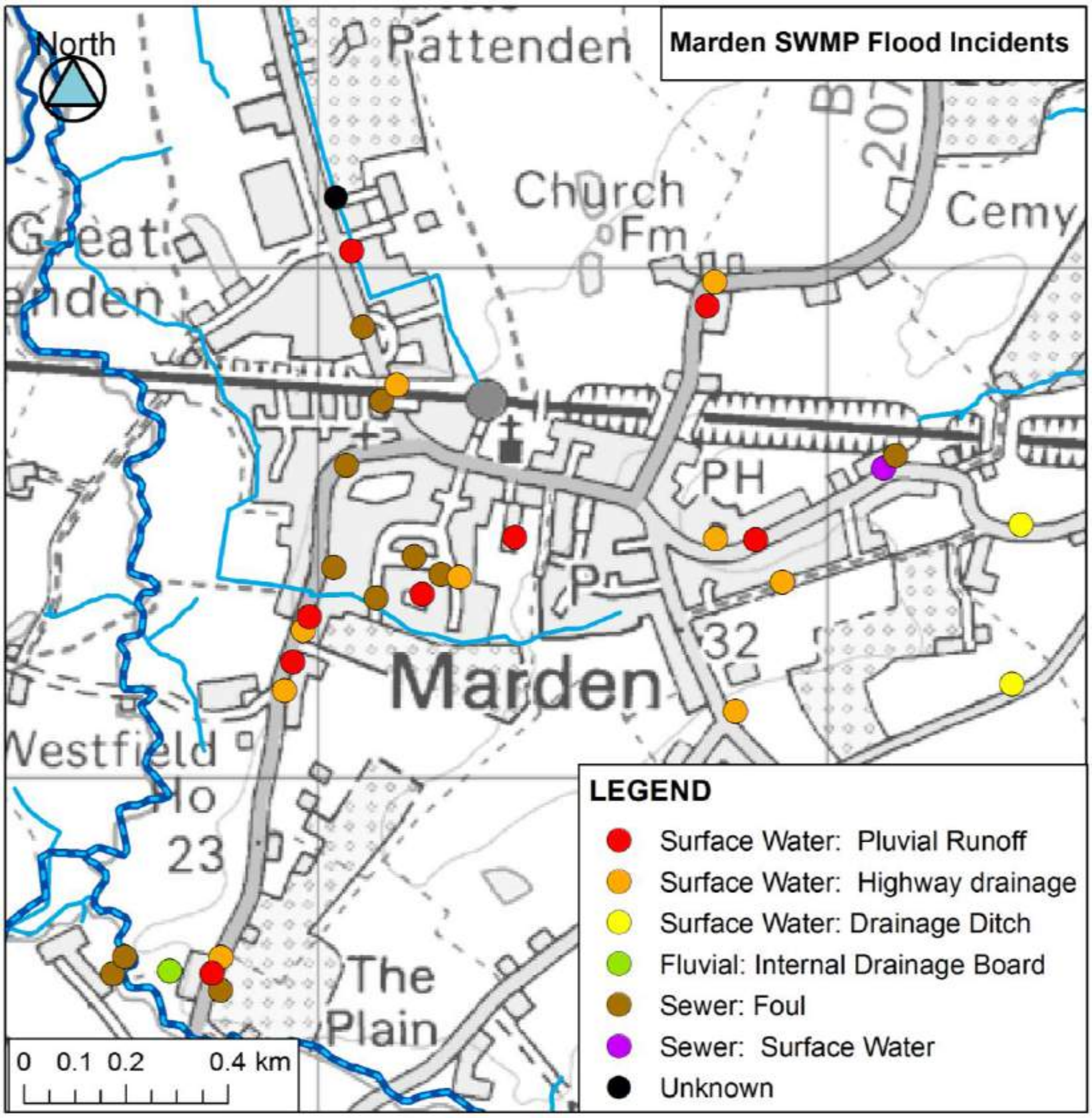





Figure 3-6 Flood history from local sources in Marden

The surface water incidents recorded have been attributed to either failing highway drainage, pluvial runoff, insufficient drainage ditches or, in one incident, overwhelmed surface water sewerage. Failing highway drainage is reportedly the most common source of surface water flood risk, leading to 19 reported incidents. Particular hotspots include Maidstone Road which has been reported on six incidents and Pattenden Lane at the railway crossing which has been reported on five incidents. On each occurrence, flooding has been reported due to blocked drainage, which suggests that routine maintenance could effectively manage the flood risk at these locations.

On Goudhurst Road where the highway drainage includes gullies and ditches, surface water flooding has been reported due to pluvial runoff, blocked highway culverts and insufficient highway culverts. Therefore, in this area maintenance should also be a priority but the flood history suggests that the current system is too small to cope with heavy deluges of rain (see section 6).

The recorded foul sewer incidents are distributed across the village. These incidents are recorded close to areas of surface water flood risk and near the Cockpit Drain. Therefore, there is potential that these flood mechanisms could be integrated. Foul only sewers should not respond to rainfall, however the flood history in Marden shows that they do. This suggests misconnections from the surface water drainage or infiltration of surface or groundwater into the sewerage. In response to this, Southern Water have completed an infiltration survey, which identified that remedial action was required at 20 manholes and 600 m of sewer in Marden to make the network more resilient to groundwater and surface water inundation. This rehabilitation work is now complete.

### 3.3.3 Patterns that lead to flooding

Analysis of past events was undertaken to understand the patterns that lead to flooding in Marden. A full report is available in Appendix B. As Marden is underlying by impermeable geology and is urbanised which created impervious areas, the catchments within Marden should be sensitive to short intense rainfall events which typically occur in summer. However, the majority of the reported flood events were in the winter months. The dates of the flood events recorded in Marden were generally associated with elevated Main River levels on the Lesser Teise and the River Beult. Therefore, it was concluded that flooding within Marden may be as a result of the inability to discharge excess surface water during Main River flood events

## 3.4 Predicted flood risk

This section discusses surface water flood risk mapping from both the national dataset and the local modelling undertaken as part of this study.

### 3.4.1 Updated Flood Map for Surface Water (uFMfSW)

National surface water flood risk mapping, known as the uFMfSW exists for England and Wales and has been published by the Environment Agency. The uFMfSW for a high probability event (3.33%), a medium probability event (1%) and a low probability event (0.1%) in the Marden area is shown in Figure 3-7.

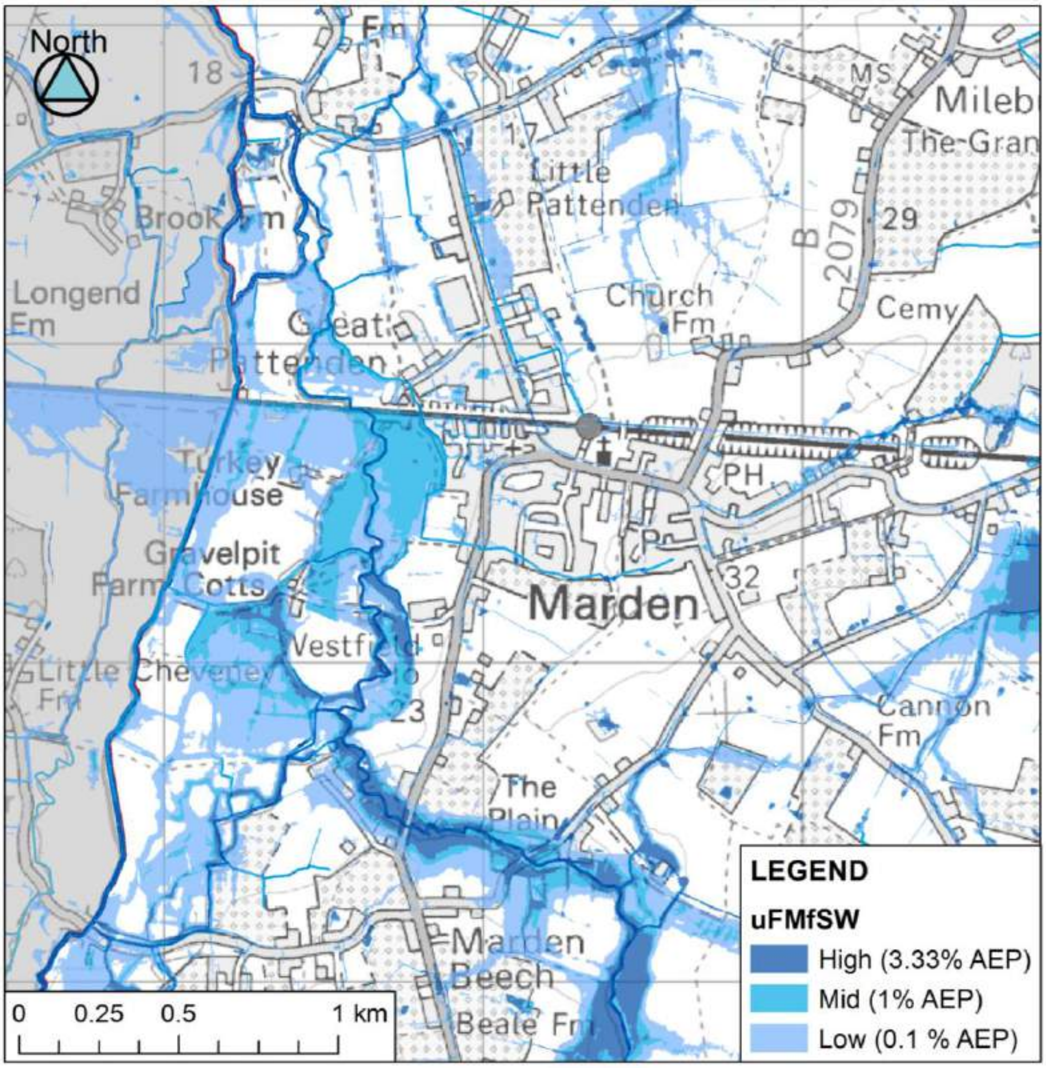


Figure 3-7 High, medium and low surface water flood risk in Marden according to the uFMfSW

The uFMfSW predicts surface water flood risk to follow the main fluvial corridors of the Lesser Teise and the Pattenden Farm. The areas of high risk are generally away from the village of Marden although there is some local ponding predicted during a 1 or 0.1 % AEP event. In the village the area of highest surface water flood risk is along Sovereigns Way, where the railway embankment impounds a natural surface water flow path and behind Howland Road where a railway culvert restricts surface water flowing north.

The uFMfSW predicts surface water ponding at the old ponds on Howland Road and the Wheelbarrow Park Estate.

### 3.4.2 Integrated Urban Drainage Model (IUDM)

An integrated modelling approach was developed as part of this study which represents all drainage systems and overland flows. The IUD model represents overland flow, public urban drainage network (highways and sewerage) and watercourses. Each of the model elements is dynamically linked to allow the exchange of flows.

The IUD model represents overland flow, public urban drainage network (highways and sewerage) and watercourses. Each of the model elements is dynamically linked to allow the exchange of flows.

#### Hydraulic Model Inflows

A full technical report describing the hydrological assessment is available in Appendix B. This section provides an overview of the hydrology and the outputs.

There have been two hydrological methods applied to the IUDM; both direct rainfall and point inflows. Flow hydrographs and rainfall hyetographs were calculated for the following Annual Exceedance Probability (AEP) events; 50%, 10%, 5%, 3.33%, 2%, 1.33%, 1% and 0.1%. The effects of climate change were considered for the 1% AEP event. For this event, rainfall was increased by 20%. Please note that new climate change guidance was published in 2016 which recommends an additional scenario is considered which includes a 40% uplift in rainfall. A 40% increase was not included in this SWMP; therefore, this is recommended for future studies.

The direct inflows were calculated using the FEH Statistical method which was appropriate because the catchments are fairly small, impermeable and mostly rural. Peak flows were derived for the Cockpit Drain and the Pattenden Farm Watercourse at the upstream and downstream of the study area. The upstream inflows were applied to the upstream of the model extent. There were no lateral inflows used because direct rainfall allowed for a distributed inflow throughout the modelled length. The downstream flow estimates were used as check flows to test that the modelled flows at the downstream extent matched with the flows calculated in the hydrology.

#### Hydraulic Model Build

A full technical report describing the IUD model is available in Appendix D. This section provides an overview of the IUD model and outputs.

Overland flow has been modelled across the parish of Marden. A digital terrain model (DTM), consisting of high resolution Lidar data supplemented with medium resolution photogrammetric data to fill gaps, has been used to inform the bare-earth topography of the catchment. Some surface features such as buildings, roads and wooded areas have also been represented as these have a direct impact on overland flow paths and velocities.

The drainage systems modelled include Southern Water's surface water sewers and Kent County Councils Highway drainage, which drain to the sewer network. The Southern Water foul sewer network has been imported from an existing Southern Water model, which was verified against a flow survey. The surface water sewers model has been built from Southern Water asset data and the highway drainage model has been built from survey data collected for this study and supplemented with existing asset data. This surface water drainage network has not been verified against a flow survey, only historic verification against reported incidents has been completed.

There are two ordinary watercourses in Marden, the Cockpit Drain and the IDB watercourse. Only the Cockpit Drain has been modelled in 1D. Due to its location through the village of Marden, and its role in receiving highway as surface water drainage it poses the largest flood risk to people and property. However, ideally the IDB watercourse would also be modelled, and this was originally planned. However, it was not possible to meet agreement to license the existing third party survey data, and therefore, the IDB drain is only modelled with a less accurate representation in 2D.

The Cockpit drain is marked with a blue line in Figure 3-8. A 1D representation of watercourses is the best way to estimate both channel capacity and in channel velocity. The 1D river model has also been connected to a 2D flood plain model at the banks of the watercourses. This allows the exceedance flows to be routed under gravity over land. Figure 3-7 also shows watercourses marked with green lines. These have been modelled in 2D only. A 2D representation still collects and conveys channel flows but the capacity of the channel is estimated from topographic data rather than survey, and can underestimate channel capacity. However, as these are low priority watercourses the steering group decided a 2D representation was sufficient.

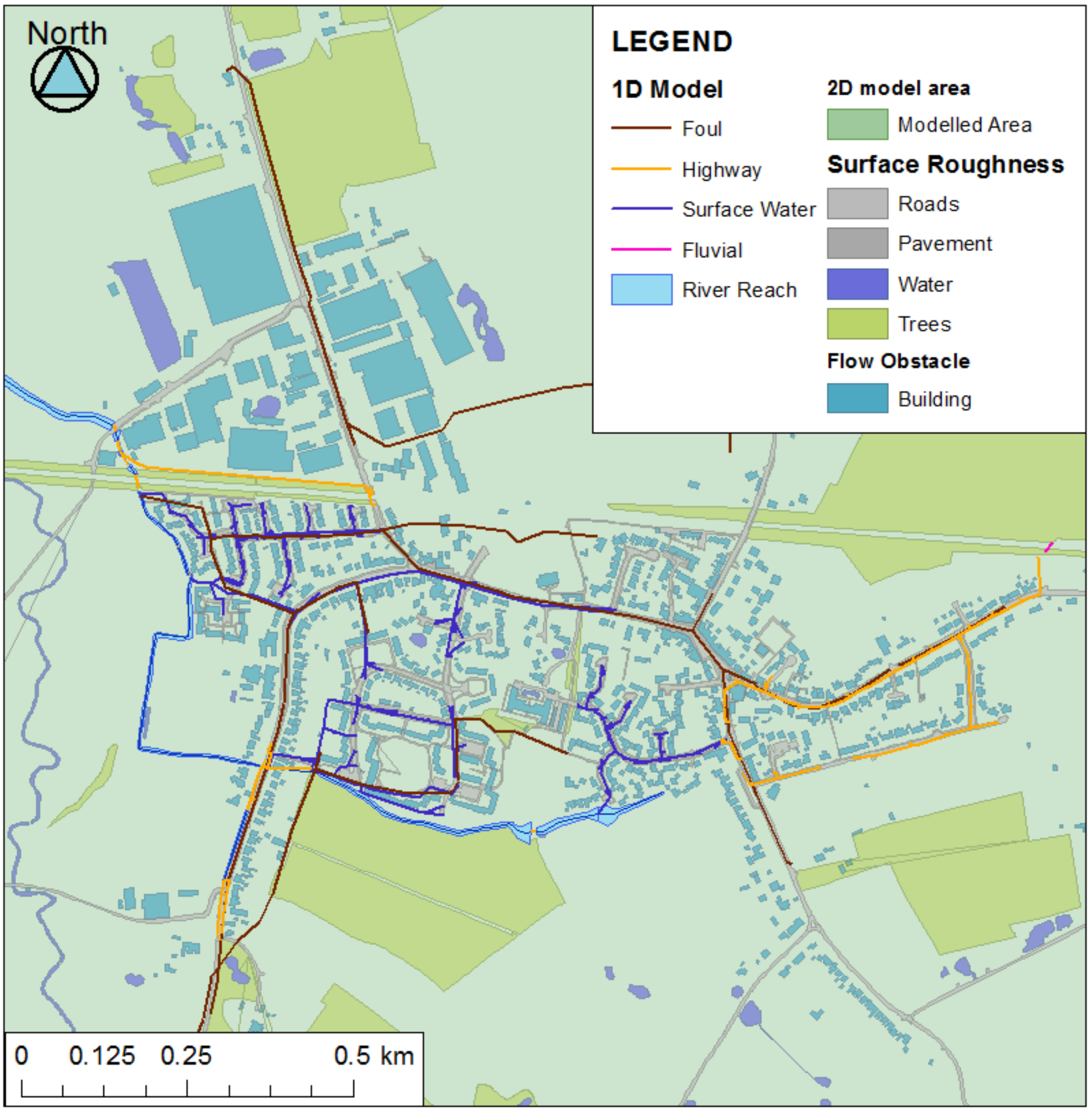





Figure 3-8: Marden IUD model schematic

### Model results

The results of the model are presented in Appendix E for the 1 in 2, 10, 20, 30, 75, 100, 100 +CC and 1000-year rainfall events. The maps show depth of flooding and the hazard to people rating, which uses a combination of depth and velocity of flow to assess health and safety hazards to people.

## 3.5 Flood risk metrics

Metrics have been used to quantify the impact of flooding at each modelled return period. Metrics consider a count of properties predicted to be at risk and an estimate of damages due to flooding based on the Multi-Coloured Manual[4].

### 3.5.1 Property counts

Property counts were based on the results from the IUDM as this was considered the best representation of flood risk in the catchment. The analysis was undertaken using Frism, a JBA GIS-based tool for analysing flood impact and damages. A detailed count was undertaken which utilises the Master Map building footprints in conjunction with the NRD property points. A property point is counted as flooded if its corresponding building footprint is within the flood outline, even if the property itself may not fall within the flood outline.

The total number of properties counted at each return period is shown in Table 3-2.

Table 3-2: Baseline property count at each Annual Exceedance Probability (AEP) event

| Flood Event Return Interval | Residential Properties Flooded | Non Residential Properties Flooded | Total |
|---|---|---|---|
| 50% AEP event | 31 | 27 | 58 |
| 10% AEP event | 60 | 79 | 139 |
| 5% AEP event | 70 | 94 | 164 |
| 3.33% AEP event | 83 | 100 | 183 |
| 2% AEP event | 89 | 116 | 205 |
| 1.33% AEP event | 94 | 132 | 226 |
| 1% AEP event | 98 | 138 | 236 |
| 0.1% AEP event | 137 | 206 | 343 |

The model results show that an increasing number of properties are flooded at each return period, as would be expected. The results suggest relatively few properties are at risk in a 50 % AEP event and the number of residential properties at risk is does not increase significantly between a 3.33 and 1 % AEP event. There are more non-residential properties at risk than residential properties. This shows how the less vulnerable land uses have been permitted in areas with greater probability of flooding. Non-residential properties predicted to flood are generally outside of the village, within the wider parish with exception of commercial buildings at Wheel Barrow Estate.

### 3.5.2 Damage calculations

Internal flooding of properties has an economic impact. The majority of financial cost is due to the damage incurred to the property (direct damages) but there are also secondary costs such as the emergency response (indirect damages) and the impact to health (intangible damages).

The damage calculation includes all of these costs. The Multi-Coloured Manual (MCM) 2013 provides a methodology for calculating damages, as well as cost versus flood depth curve which has informed this assessment.

A property threshold level of 0.15 metres has been assumed. This means that if a property is intersected by a flood depth less than 0.15m, it has been assumed that no direct damage will be incurred as the flood water could not access the property.

The damages curve for each of the properties was adjusted to account for inflation. This was done by using the monthly variation of the Customer Price Index (CPI) which was inputted at 132.6. The CPI uses the prices of a representative sample to statistically estimate the variation in the real property value whilst accounting for the changes in the rate of inflation.

The economic damages estimated for the baseline scenario for each Annual Exceedance Probability (AEP) is shown in Table 3-3.

[4] Middlesex University (2013) Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal.

Table 3-3: Baseline damage calculation at each Annual Exceedance Probability (AEP) event to the nearest £k

| Flood Event Return Interval | Residential (£) | Commercial (£) | Total Damage (£) |
|---|---|---|---|
| 50% AEP event | 332,000 | 2,694,000 | £3,026,000 |
| 10% AEP event | 689,000 | 3,628,000 | £4,317,000 |
| 5% AEP event | 886,000 | 3,846,000 | £4,732,000 |
| 3.33% AEP event | 985,000 | 4,133,000 | £5,118,000 |
| 2% AEP event | 1,132,000 | 4,352,000 | £5,484,000 |
| 1.33% AEP event | 1,286,000 | 4,799,000 | £6,085,000 |
| 1% AEP event | 1,363,000 | 4,985,000 | £6,348,000 |
| 0.1% AEP event | 2,153,000 | 4,982,000 | £7,135,000 |

## 3.6 Flooding hotspots

A flooding hotspot is an area identified as prone to flooding according to local knowledge, flood history or flood risk mapping. These include the Cockpit, Howland Road and the western side of the Wheelbarrow Industrial Estate.

### 3.6.1 Cockpit

The Cockpit in Marden (Figure 3-9) has a history of flooding from surface water and foul sewers. The uFMfSW predicts that most of the Cockpit are is at very low risk of surface water flooding, but that there is an area of low risk on The Maynards which is corroborated by the IUD model results. The IUD results indicate that event during a 0.1% AEP event the Cockpit Drain has capacity to convey flows so the fluvial flood risk from the Cockpit Drain is very low.




Figure 3-9: The Cockpit, Marden

Within the Cockpit hotspot there are a number of drainage assets. The key assets are listed in Table 3-4.

Table 3-4: Drainage assets at the Cockpit

| Asset | Owner | Comments |
|---|---|---|
| Separate surface water and foul sewerage system | Southern Water | A surface water siphon has been identified. The purpose of this siphon is not known.<br>The rising main from Sovereigns Way foul water pumping station discharges to the foul system near 27 The Cockpit. |
| Cockpit Drain | Riparian owners | On the site visit in November 2014 some fly tipping was observed with could lead to blockages on the watercourse. |
| Few highway gullies | KCC highways | On the site visit in November 2014 some of the highway gullies were blocked. Report suggest that blocked gullies has led to flooding here. These were subsequently cleansed in July 2016. |
| Infilled pond | NA | A pond was identified from old mapping. This was located to the south of the area now the playground in the centre of the Cockpit estate. |

Hydraulic overload of the foul sewerage in and around the Cockpit has been reported. This suggests that unplanned flows are accessing the sewerage via misconnections, groundwater infiltration or surface water inundation. Misconnections have not been investigated as part of this SWMP as it is beyond its remit. However, the chance of groundwater and surface water inundation has been considered. The IUD model results indicate that the foul infrastructure is at risk of surface water inundation from Maynards and West End, but even with the surface water ingress represented in the model, no flooding from the foul drainage to be predicted, even at a 1% AEP event. Infiltration from groundwater could occur despite the impermeable geology. Generally, clay soils have a close texture which limits is permeability. However, the sewers are laid in trenches which are back filled with gravel. This gravel filled trench can acts as a conveyance route for groundwater through an otherwise impermeable soil and as a result can have locally raised water table. Groundwater can then infiltrate into the sewer if there are defective pipe joints or cracks in the sewer. It is possible that groundwater infiltration is a main source of unplanned flows in the foul sewerage at the Cockpit, but further study would be required to confirm that. Therefore, this is included in the Action Plan.

The IUD model predicts surface water flood risk in the Cockpit which could impact properties. The source of the runoff was the open space in the centre of the Cockpit estate. Surface water flooding at the Cockpit has been reported when gullies on the footpath are blocked. Therefore, an action to cleanse these gullies has been included in the Action Plan.

Fluvial flood risk from the Cockpit is predicted but only to the source of the watercourse. This area is now being considered for development, and the potential for fluvial flooding should be considered when designing the site layout.

### 3.6.2 Howland Road

Howland Road in Marden (Figure 3-10) has a history of flooding from foul and surface water drainage. Reported receptors to flooding include residential curtilage and highways.

The uFMfSW and IUD model both predict that the properties north of Howland Road are at high or medium risk of surface water flooding.




Figure 3-10: Howland Road, Marden

The key drainage assets in in the Howland Road hotpot are listed in Table 3-5.

Table 3-5: Drainage assets at the Howland Road hotspot

| Asset | Owner | Comments |
|---|---|---|
| Foul sewerage system | Southern Water | A foul only drainage system drains west to Howland Road pumping station. |
| Highway drainage | KCC highways | A highway drain runs eastward from Howland Road and Stanley Road. This asset was surveyed as part of this study although not traced to outfall.<br>KCC undertook remedial work on the highway drainage in 2014. |
| Railway culvert | Network Rail | At time of last inspection, the railway culvert was partially blocked and has been recommended for clearance since 2012. A CCTV survey completed by the Howland Road developer in September 2013 showed this culvert to be clear, however, this contradicts the asset inspection by Network Rail in November 2013. |
| Infilled pond | NA | A pond was identified from old mapping. This was located north of Howland Road which is now residential curtilage. |

Hydraulic overload of the foul sewerage has been reported on Howland Road. As there is no surface water sewerage at this location it is assumed that there are a number of surface water connections into the foul sewer which would lead to overload. The uFMfSW and IUD models both predict surface water flood risk to Howland Road and the properties north of Howland Road.

Surface water inundation of the system is predicted upstream of the pumping station which could cause the pump to operate longer and more frequently than designed. As a result, Southern Water has planned works to improve resilience to surface water inundation at the pumping station.

Surface water ponding occurs north of Howland Road particularly at the site of the infilled pond. The road is higher than the properties at this location so runoff from the highway could drain down towards the houses. Work was completed by Kent County Council Highways Department in 2014 to repair the highway drainage network which has significantly contributed to managing the surface water flood risk here.

The culvert under the railway is key drainage route for surface water at Howland Road. This asset is partially blocked by sediment and surveys since 2012 have recommended clearance. However, CCTV survey in 2013 suggested the culvert was clear. It is likely that the reduced capacity of this culvert is increasing surface water flood risk in Howland Road and the surrounding area, therefore despite the conflicting information, culvert clearance has been included in the Action Plan.

### 3.6.3 Wheelbarrow Estate

Commercial properties on the Wheelbarrow Estate have experienced internal flooding twice, most recently during the winter 2013 - 2014 event.

The uFMfSW predicts that the area south of the railway is at medium risk of surface water flooding whereas the area to the north of the railway line is at very low risk of surface water flooding. The IUD model shows that the Wheelbarrow Estate is at high risk of fluvial flooding from the Lesser Teise and medium risk of fluvial flooding from Pattenden Farm Drain and the Cockpit Drain when the Lesser Teise is high.

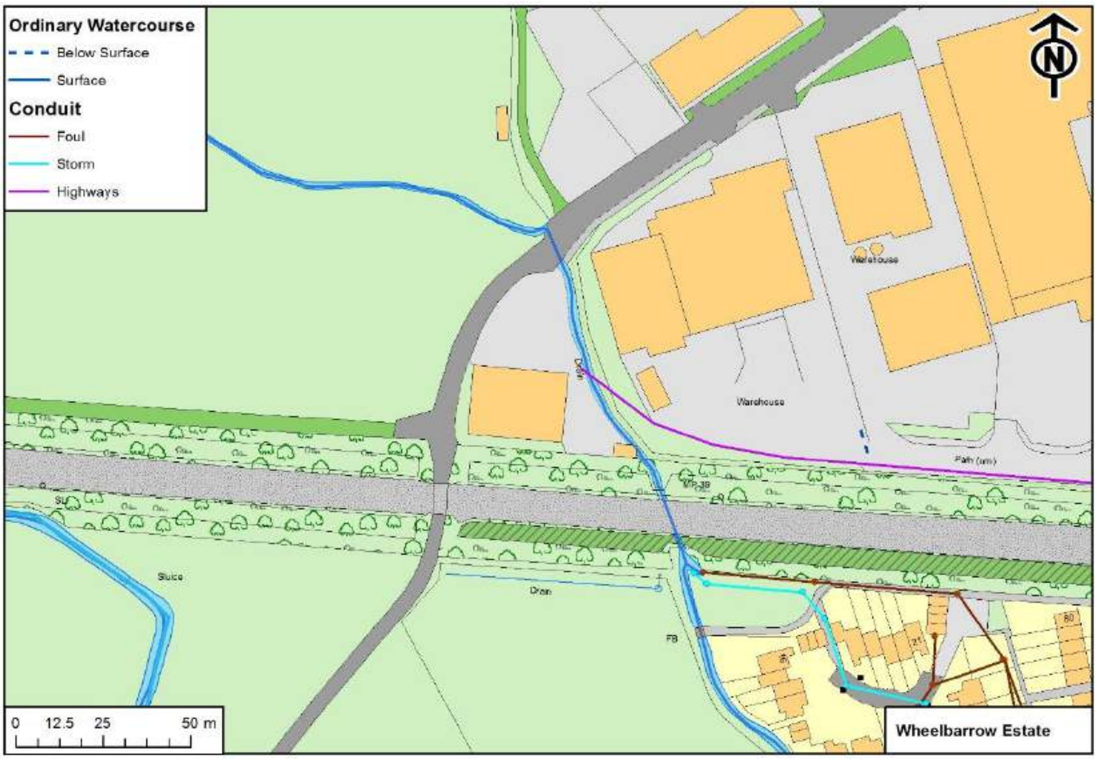





Figure 3-11: Wheelbarrow Estate, Marden

The key drainage assets in the Wheelbarrow Estate hotspot are listed in Table 3-6.

Table 3-6: Drainage assets in the Wheelbarrow Estate hotspot

| Asset | Maintainer | Comments |
|---|---|---|
| Cockpit Drain | Riparian Owners | The Cockpit Drain passes under the railway and have been informally culverted by |

| Asset | Maintainer | Comments |
|---|---|---|
| | | riparian owners on the Wheelbarrow Estate. During the site visit it was observed that the open stream downstream of the access road overgrown |
| Highway Drainage | Network Rail/ KCC highways | A highway drain passes through Network Rail land and is assumed to discharge into the Cockpit Drain. |
| Pattenden Farm Drain | Medway IDB | The Pattenden Farm Drain floods out and into the Cockpit Drain. |
| Lesser Teise | Environment Agency | The Lesser Teisse is predicted to back up to the Wheelbarrow Estate during a 20% AEP event. |

The IUD model shows that the flood risk from local sources to the Wheelbarrow Estate is only likely when the water levels in the River Teise are high. The fluvial flood risk from Main Rivers is the predominate cause of flooding at this location and is thought to be the primary source of flooding in the winter of 2013/ 2014. One way to manage fluvial flood risk is to improve property resilience by the adoption of Property Level Protection. However, as the properties at the Wheelbarrow Estate are industrial, there will not be any public funding available for property level measures. Therefore, this would have to be a private investment.

The capacity of the Cockpit drain could be increased if the vegetation was cleared or the culverts formally designed, but this would be the responsibility of the riparian owner. This has been included in the Action Plan.

## 3.7 Validation of the risk assessment

A variety of approaches have been taken to validate this risk assessment, as outlined in the following sections.

### 3.7.1 Model verification against hydrometric data

To verify sewer flow models Water Companies, undertake in pipe flow and level surveys accompanied by a network of rain gauges. These are often temporary and remain in the ground long enough to record three storms of sufficient depth and intensity with which to verify the model against. This detailed verification process compensates for not being aware of the condition of the piped network or the exact contributing areas. The parameters can be adjusted to produce results that represent what occurred in the catchment. However, short-term flow surveys are expensive and therefore are prioritised towards key assets; which for a water company are rarely surface water sewerage networks. As a result, there is no in pipe flow data to verify this model against.

Therefore, the verification has focussed on matching the predicted surface water flow paths and pooling areas with the reports of flooding.

### 3.7.2 Model review meeting

The baseline model results were presented to the project steering group for their approval based on local knowledge of flood mechanisms as discussed in Section 3.7. This meeting found that the flood extents predicted at Howland Road and Goudhurst Road matched well with flood extents observed in the winter of 2013/2014. However, the flooding at the Wheelbarrow Estate under predicted what was observed. This led to testing of downstream boundaries on the model and the understand that flooding at the Wheelbarrow Estate is driven by the Lesser Teise rather than the Cockpit Drain or Patternden Farm Drain.

### 3.7.3 Historic events

Southern Water records flood events from sewers. The data they have provided for this project is a count of flooding incidents within a seven-digit postcode. The data has been supplied in this format to respect their customer's confidentially. Therefore, its uses for model validation are limited, as we do not know if the flooding was from a foul or surface water sewer and where the incident occurred exactly.

Kent County Council highways keep a log of flooding incidents. This highlights stretches of road that have had flooding and occasionally, point data of where the flooding has occurred. This more precise data is more useful for model validation. As a result, this data set has been the primary source of information for model validation. Further discussion of historic flooding datasets can be found in section 3.2.

Locations where pluvial runoff have been reported have been well represented by the IUD model, with Howland Road, Goudhurst Road, Pattenden Lane and the Cockpit all predicting flooding where pluvial runoff has been reported. However, surface water runoff is also predicted on Park Road and Thorn Road which has not been reported. Flooding from surface water when drainage was blocked has been reported on Stanley Road and Maidstone Road which is not predicted by the IUD model. In the model as it is assumed that all assets are free of obstruction, therefore it is possible the surface water flooding at these locations could be avoided if the drainage network was running clear.

# 4 Development

Maidstone Borough Council is in the process of revising their Local Plan which will set the framework for development in the Borough. The draft Local Plan defines Marden as a rural service centre[5] and the policy for Marden includes development of 447 new residential dwellings over five sites and 21,300m$^2$ employment floor space over two sites. Marden Neighbourhood Plan is currently under development which will set policies on development relevant to the Parish of Marden.

Surface water flooding is exacerbated by urbanisation when natural, permeable land uses are replaced with impermeable surfaces. However, the impact can be mitigated if KCC and Maidstone Borough Council guidance on the management of surface water is followed in the design of new developments. The guidance recommends the use of sustainable drainage systems (SuDS) which mimic natural systems and reduce surface water runoff and pollution. National Planning Policy Framework (NPPF) recommends that where possible development should be an opportunity to reduce flood risk. Developers are not required to solve existing flooding problems off their site, though they are encouraged to provide betterment through NPPF, and appropriate management of runoff at a development site could reduce flood risk elsewhere. If this is supported by local planning policies, it is more likely to be delivered by developers.

This section examines the location of allocated development sites in relation to known hotspots and considers how development could change flood risk in Marden.

## 4.1 The Parsonage

The Parsonage is allocated for development of approximately 140 dwellings. The area allocated in illustrated in Figure 4-1.

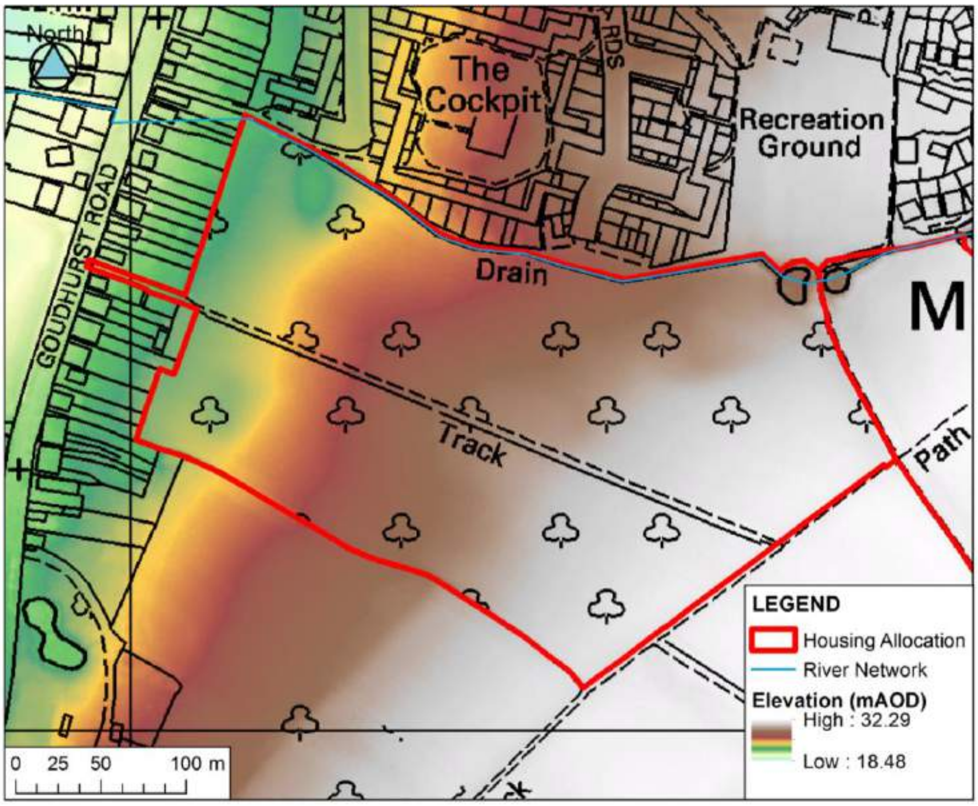





Figure 4-1: The Parsonage allocated development site

5 http://consult.maidstone.gov.uk/portal/mblp_r18_oct_15?pointId=3487824

The site is due south of the Cockpit flooding hotspot, and drainage from the development would contribute to the Cockpit drain. The IUD model predicted fluvial flood risk from the Cockpit Drain to this development site, and this should be considered in the master planning any development. Additional surface water discharge upstream of Goudhurst Road into the Cockpit Drain would exacerbate the existing fluvial flood risk and should be managed with a suitable surface water drainage strategy.

There are records of foul sewer surcharge at the Cockpit and any new development should have no detriment to existing flooding problems. Southern Water should be consulted to enable the design of an effective foul drainage system.

## 4.2 Howland Road

Howland Road is allocated for development of approximately 40 dwellings. The area allocated in illustrated in Figure 4-2.

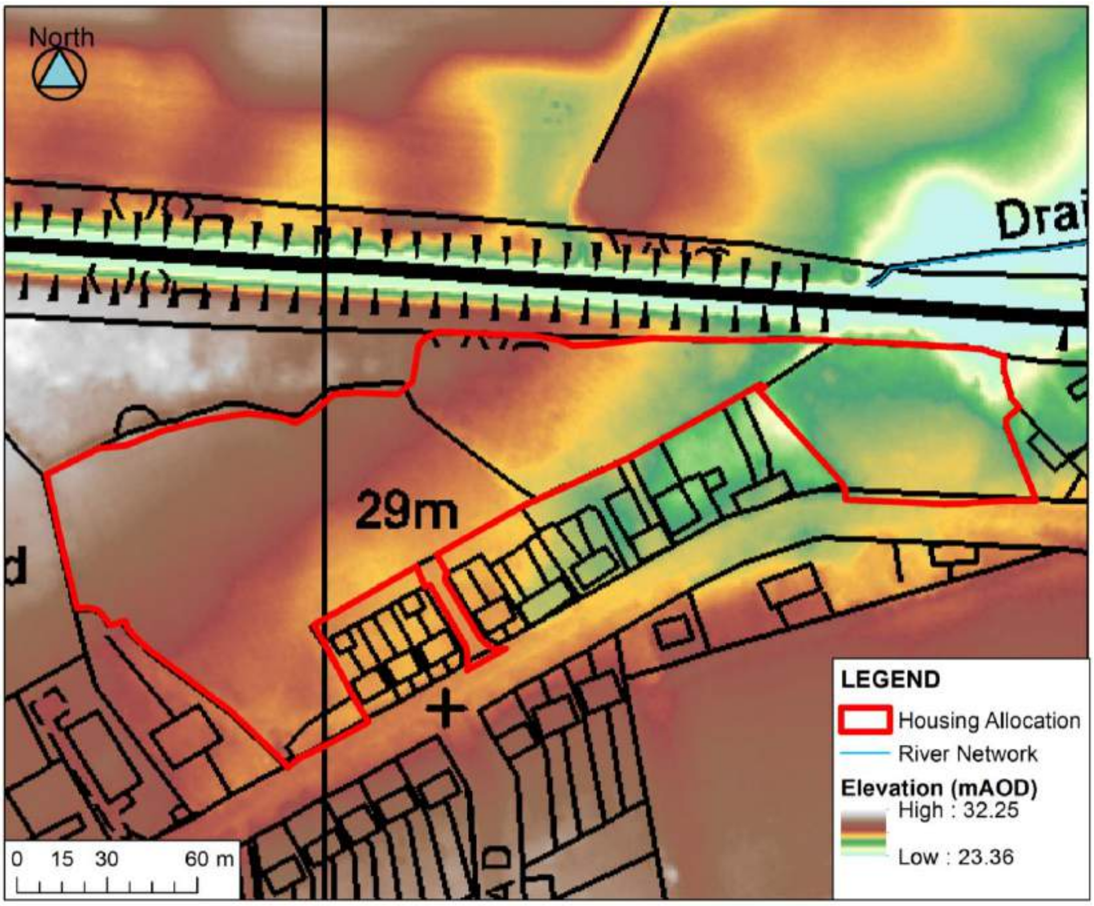





Figure 4-2: Howland Road allocated development site

Permission for this development was granted in July 2014. This permission predated the SWMP and the role of Kent County Council as statutory consultee on planning applications. The development proposal included a surface water attenuation pond in the plans, but as permission is granted, it is not possible to use this development as opportunity to further manage the existing surface water flood risk.

After the attenuation basin, surface water would drain north, under the railway line. The developer undertook a CCTV survey in September 2013 to ascertain the condition of the railway culvert. This found the culvert to be clear, which contradicts the visual inspection completed by Network Rail in December of 2013. The developer should consult Network Rail to determine culvert condition at the time of construction as free flow under the railway line could be critical to effective drainage from the site.

There are records of foul sewer surcharge on Howland Road. The developer would be expected to work with Southern Water to develop a foul drainage strategy that provides sufficient drainage to the site and avoids detriment of service to existing customers.

## 4.3 Wheelbarrow Estate

The land west of the Wheelbarrow Estate is allocated as an employment site with approximates 15,000 m$^2$ of floor space. The allocated area is illustrated in Figure 4-3.

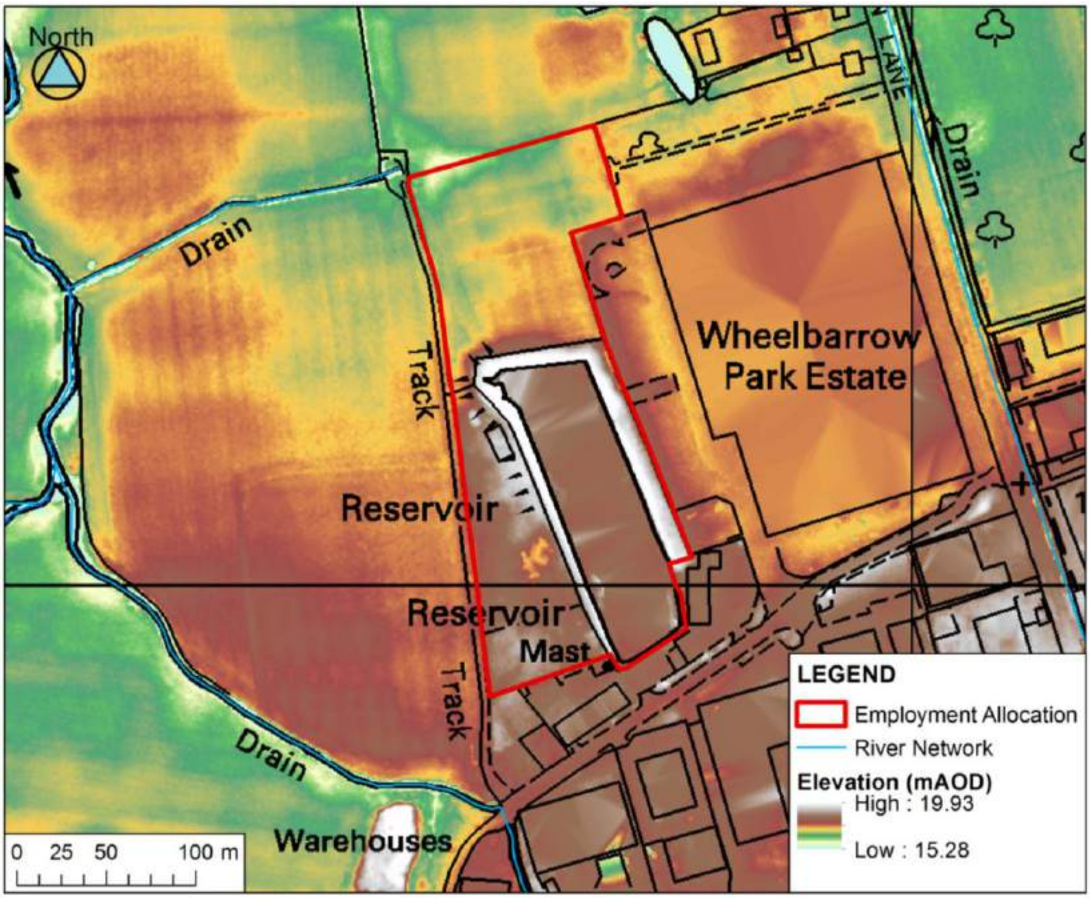





Figure 4-3: Wheelbarrow employment allocation site

Industrial land uses often have a high percentage impermeable land cover and can generate large volumes of runoff. However, there is also the opportunity to implement techniques such as rainwater harvesting, permeable paving and bio-retentions devices that manage surface water and provide water resources or amenity areas.

The development site is located downstream of Marden therefore runoff from development is unlikely to impact the existing hotspot. However, the flood risk from the Lesser Teise should be considered in a detailed Flood Risk Assessment. The development would include the draining and infill of an existing reservoir. A method statement to ensure the prevention of flooding from reservoir breach should be completed prior to any works.

# 5 Options

A full list of potential options to mitigate flood risk in Marden can be found in Appendix F. This includes indicative costs and benefits of each measure. This section provides an overview of the options appraisal process and the outputs.

## 5.1 Objectives

The objective of the options assessment process was to identify, shortlist and assess a suite of measures (individual actions or procedures to manage current and future surface water flood risk, or to meet other SWMP objectives) for mitigating surface water flooding and agree preferred options (a single measure or combinations of measures) across the study area. The preferred options are then included in the Action Plan.

## 5.2 Options appraisal

The options appraisal first looked at opportunity and needs in the Marden Parish. It was agreed during the options workshop that the areas in greatest need of intervention were the flooding hotspots and these were the focus of the options assessment. The opportunities considered current land use and planned activities. A preliminary 'long list' of options was developed which considered multiple methods to manage the flood risk. The options were then whittled down to a short list which were considered the most effective and feasible. These were then tested in the hydraulic model.

### 5.2.1 Opportunities

Opportunities have been identified where there may be opportunities to manage surface water by retrofitting SuDS (such as large flat roofs and open green spaces), store fluvial exceedance such as open spaces or agricultural land or where work is already planned and efficiencies could be realised by combining programmes.

There are currently no planned schemes in Marden. However, this SWMP has aligned with preparation of the Southern Water Drainage Area Plan which has allowed for effective sharing of information and survey data (for example KCC's gully survey).

As discussed in Section 4, the proposed development could be an opportunity to manage flood risk in Marden and the surrounding area. Intelligent use of SuDS should enable surface water to be managed at the site and avoid increasing runoff elsewhere. Suitable drainage strategies should be prepared by the developer, noting the potential constraints listed above.

Opportunities to retrofit SuDS in Marden considered current green spaces and limitations such as narrow footpaths, buried services or need for parking. Areas suitable for SuDS retrofit include Howland Road, the Cockpit and the Wheelbarrow Estate. Highway drainage is already managed in an open ditch system on a section of Goudhurst Road but flood history suggest that surface water flooding has been a reoccurring issue in this location which highlights the importance on maintenance of green infrastructure.

### 5.2.2 Needs

The area of greatest need for flood management from local sources in Marden have been identified as:

- The Cockpit
- Howland Road
- The Plain
- The Wheelbarrow Estate

### 5.2.3 Short list of options

The short listed options have been summarised in Table 5-1 and displayed in Figure 5-1.

Table 5-1: Shortlisted options for Marden

| Hotspot | Option | Purpose |
|---|---|---|
| The Cockpit | Infiltration basin at the Cockpit | Divert a surface water flow path way from properties and prevent surface water inundation of foul sewerage. |
| Howland Road | Manage surface water flow paths on the highway | Divert surface flows away from properties. |
| | Manage surface water flow paths in a swale | |
| | Manage surface water flow path in a detention basin | Store flow which is restricted by railway culvert. |
| The Wheelbarrow Estate | Lower the access road | Encourage fluvial flooding to bypass the estate along access road. |
| The Plain | Raise the highway | Maintain access along The Plain during periods of fluvial flooding from Pattenden Farm Drain |

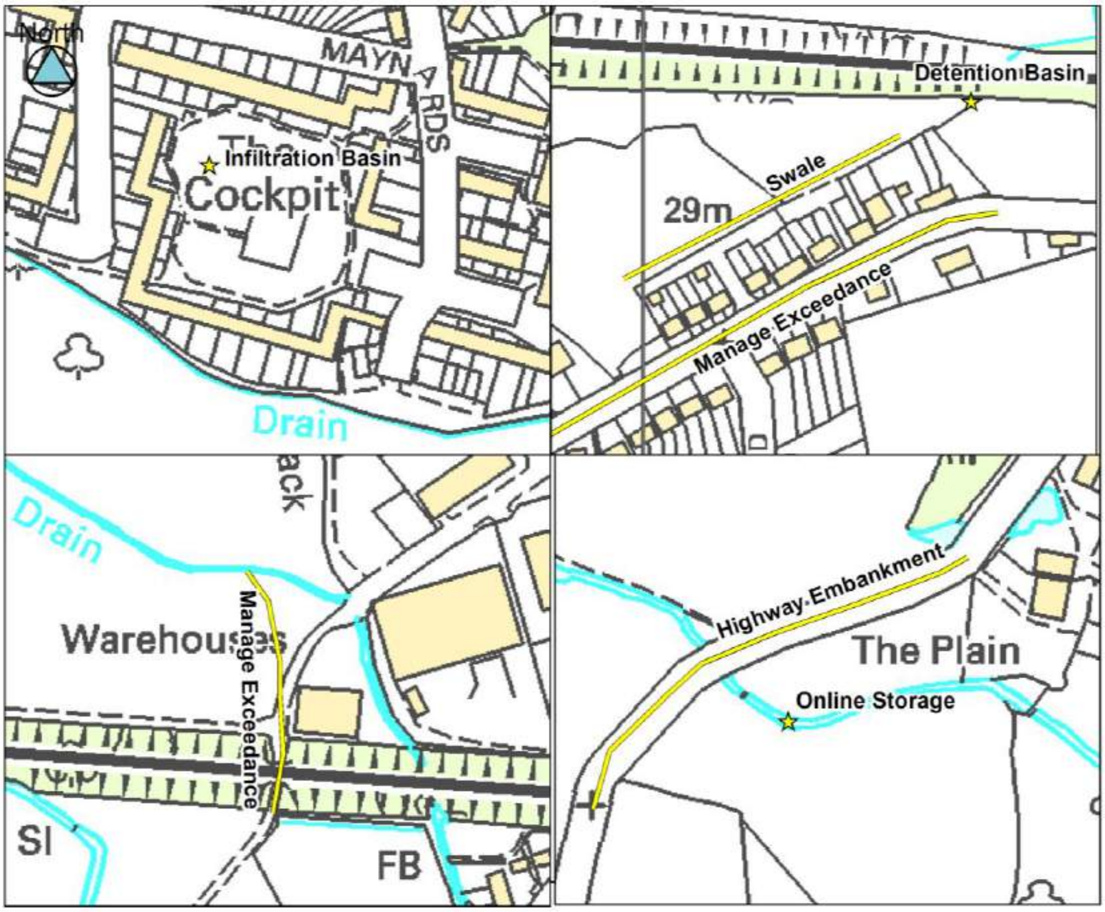





Figure 5-1: Location of shortlisted options for Marden

The options were then tested and refined in the hydraulic model. The performance of each model was tested against the baseline model.

### 5.2.4 Results

The results showed that an infiltration basin at the Cockpit is an affective measure to trap overland flows and prevent £11,000 of damages to residential properties. However, the cost of an infiltration basin was over twice as high as the benefits predicted to be brought about. During the options workshop KCC raised concerns that an infiltration basin in this impermeable catchment is likely to take a long time to drain down and would reduce the amenity value of the green space. As a result, a positively drained solution was sought. However, there was no option to discharge directly to the Cockpit Drain due to the location of housing and Southern Water and KCC highways do not take land drainage. Therefore, it is considered that this option is neither cost beneficial or practicable at this time.

The option appraisal of Howland Road found the most affective opportunity to manage surface water was to combine the swale behind properties and the attenuation basin upstream of the railway culvert. However, the predicted flood damages were only reduced from £9,000 to £8,000 under this option because rainfall continued to pond directly on properties. As a result, the estimated costs of the SuDS outweighed the flood damage benefits at 52:1. Therefore this option is not cost beneficial. However, the swale and attenuation basin SuDS features should be considered as part of the drainage design if the Howland Road development progresses.

Under the current conditions £14,000 of flood damages was predicted during a 1% AEP rainfall event at the Wheelbarrow Estate. This is reduced to £10,000 if an exceedance route is implemented. However, the estimated cost is lowering the private road is three times greater than the predicted benefits. Therefore, this option is not cost beneficial. In addition, these properties are predicted to flood from the Lesser Teise at a 20% AEP fluvial event, and an exceedance route would not protect these properties from this flood risk. As a result, the exceedance route is not a sustainable use of public resources as the properties would remain at frequent flood risk.

Finally, options were tested to retain access to Marden via The Plain during a 1% AEP event. The testing concluded that if the highway remained at the present level, the storage required to maintain access would be impractically large. Therefore, storage was considered in combination with highway raising. The construction of a raised highway embankment is hugely expensive but no benefit was predicted to properties at risk. As a result, the costs outweighed the benefits at a ratio of 135:1. Therefore this option is not cost beneficial. In addition, access to Marden can be achieved via alternative routes. Therefore, the closure of The Plain is an inconvenience rather than a health and safety risk to residents.

As none of the cost benefit ratio were sufficiently strong, it is not recommended that any options tested are progressed to design stage at this time. However, options at the Cockpit and Howland Road should be considered if other works are undertaken and particularly alongside any development at the Howland Road site.

# 6 SWMP Action Plan

## 6.1 Introduction

This section sets a plan for managing the flood risk identified in this SWMP. The action plan uses all the information collated during the SWMP process to recommend measures to reduce or mitigate the flood risk in Marden and:

- Outlines the actions required and where and how they should be undertaken;
- Sets out which partner or stakeholder is responsible for implementing the actions and who will support them;
- Provides indicative costs; and
- Identifies priorities.

The action plan is divided into two components; the generic action plan and the site specific action plan.

Table 6-1: List of action plans

| Geographic area | Action plan | Purpose |
|---|---|---|
| Study area wide | Generic action plan<br>(Section 6.2) | Outline broad scale actions applicable across the study area |
| Hotspots | Hotspots action plan<br>(Section 6.3) | Recommend strategic actions to manage the flood risk in hotspots |

## 6.2 Generic Action Plan

Some of the actions derived during this SWMP are applicable to the whole SWMP area of Marden. Actions to mitigate these issues are listed in the generic action plan.

Table 6-2: Generic action plan for Marden

| Reference | Action | Action owner | Priority |
|---|---|---|---|
| GAP01 | *Maintain the partnership*<br>The ongoing partnership will discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes. | All | High |
| GAP02 | *Sustainable development*<br>It is recommended that the planning authority incorporate the findings of this SWMP, thereby raise issues to developers through its local plan to allow for pre-emptive flood risk reduction during the planning process. Sustainable drainage systems should consider the landscape character of Marden and consider the incorporation of ponds, as are common in the parish. | MBC and MPC | High |
| GAP03 | *Asset maintenance*<br>Optimise the routine asset inspection and maintenance to prevent flooding occurring as a result of malfunctioning highway drainage or sewerage. | Network Rail/ KCC highways/ Southern Water | High |
| GAP04 | *Flood warden*<br>KCC and the EA have trained flood wardens in the neighbouring parishes and this would also be available to Marden. Trained flood wardens can | MPC | Mid |

| | | | |
|---|---|---|---|
| | improve flood resilience enacting a community flood plan. | | |

## 6.3 Hotspot Action Plan

Table 6-3 describes the action plan for specific locations. The site specific action plan phases work, to provide a step by step guide for implementation. Some of the later actions will only be required if earlier actions do not resolve the flooding issue. Ongoing monitoring of flood incidents is essential to assess the impact of these actions.

Table 6-3: Site specific actions for Marden

| Ref | Area of benefit | Problem | Action | Benefits | Action Owner | Supporter | Priority | Indicative Cost* |
|---|---|---|---|---|---|---|---|---|
| MAR01 | The Cockpit | Foul and surface water flooding has been reported on the estate. | 1. Cleanse footpath gullies<br>2. Establish where footpath gullies drain to<br>3. Investigate an infiltration basin in the open space – test local infiltration potential and establish whether this could also discharge to existing highway drainage? | Maximise the existing drainage and minimise flooding to the Southern Water sewers | KCC Highways | SW, KCC | 1. High<br>2. Mid<br>3. Mid | 1. Low<br>2. Mid<br>3. High |
| MAR02 | Howland Road | Surface water flooding has occurred and the predicted risk is high. The flow passes under then railway which has been blocked. Over time the Howland Road has raised, leaving the old properties lower than road level. KCC Highways have repaired highway drainage which helps better manage surface water. A planning application at Howland Road was granted permission in 2014. | 1. Confirm culvert condition with Network Rail at the time of construction<br>2. Protect existing drainage assets during construction | Maximise the existing drainage | 1. Developer<br>2. Developer | 1. Network Rail<br>2. KCC | 1. High<br>2. High | 1. Low<br>2. Mid |
| MAR03 | Wheelbarrow Estate | Fluvial flood risk effects this site from the Lesser Teise and the Cockpit Drain. It was flooded in 2014. Please note, industrial | 1. Increase the properties resilience to flooding by adopting private property level protection and signing up for flood warnings | Reduce the impact of flooding | Land owner | KCC | High | Low |

| Ref | Area of benefit | Problem | Action | Benefits | Action Owner | Supporter | Priority | Indicative Cost* |
|---|---|---|---|---|---|---|---|---|
| | | buildings are not eligible for public funding for Property Level Protection. | 2. Maintain the Cockpit Drain downstream of the estate to improve conveyance | | | | | |
| MAR04 | Goudhurst Road | Surface water flooding has occurred as a result of surface water drainage systems and ditches being undersized or blocked | 1. Cleanse highway drainage and clear drainage ditches and culverts<br>2. Develop asset maintenance scheme which prioritises this area.<br>3. Consider upgrading highway drainage if flooding persists | Maximise the existing drainage | KCC Highways | | 1. High<br>2. High<br>3. Low | Low |
| MAR05 | Plain Road | Fluvial flooding makes this road impassable, limiting access to and from Marden. Raising the road was not found to be cost beneficial. | 1. Consider Plain Road for inclusion in the traffic management during flooding project<br>2. Install signage to inform motorists that the road is liable to flooding<br>3. Use emergency planning process to establish a road closure and diversion process | Increase awareness and therefore safety | 1. KCC<br>2. KCC Highways<br>3. KCC Highways | 1. KCC Highways | Low | Low |

** Indicative Cost: Low = Up to 50k, Mid = 50-150k, High = 150-250k or 250+k*

| | | | | | | |
|---|---|---|---|---|---|---|
| *EA: Environment Agency* | *KCC: Kent County Council* | *KCC Highways: Kent County Council Highways* | *MBC: Maidstone Borough Council* | *MPC: Marden Parish Council* | *NR: Network Rail* | *SW: Southern Water* |

## 6.4 Review timeframe and responsibilities

High priority actions identified in the 'Action Plan' are likely to be those addressed first. However, this report can only consider relative priorities within Marden. Some partner organisations, including the Environment Agency, Southern Water and Kent County Council have flood risk management responsibilities beyond the geographic scope of this study, and therefore the priority of actions within Staplehurst will have to be assessed against actions in other areas. Kent County Council is currently undertaking SWMPs in a number of other settlements across the county and delivering existing Action Plans.

It is recommended that, an annual review of the High and Medium Priority actions is undertaken. This will allow for forward financial planning in line with external partners and internal budget allocations. Low priority actions should be reviewed on a three-year cycle.

## 6.5 Sources of funding

Funding for local flood risk management may come from a wide range of sources. In Marden these may include:

- Defra (Flood Defence Grant in Aid)
- Kent County Council (highways)
- Southern Water
- Industrial estate owners and businesses
- New developments (directly through the developer or through CIL)
- Local communities
- Maidstone District Council

## 6.6 Ongoing monitoring

The partnership arrangements established as part of the SWMP process should continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

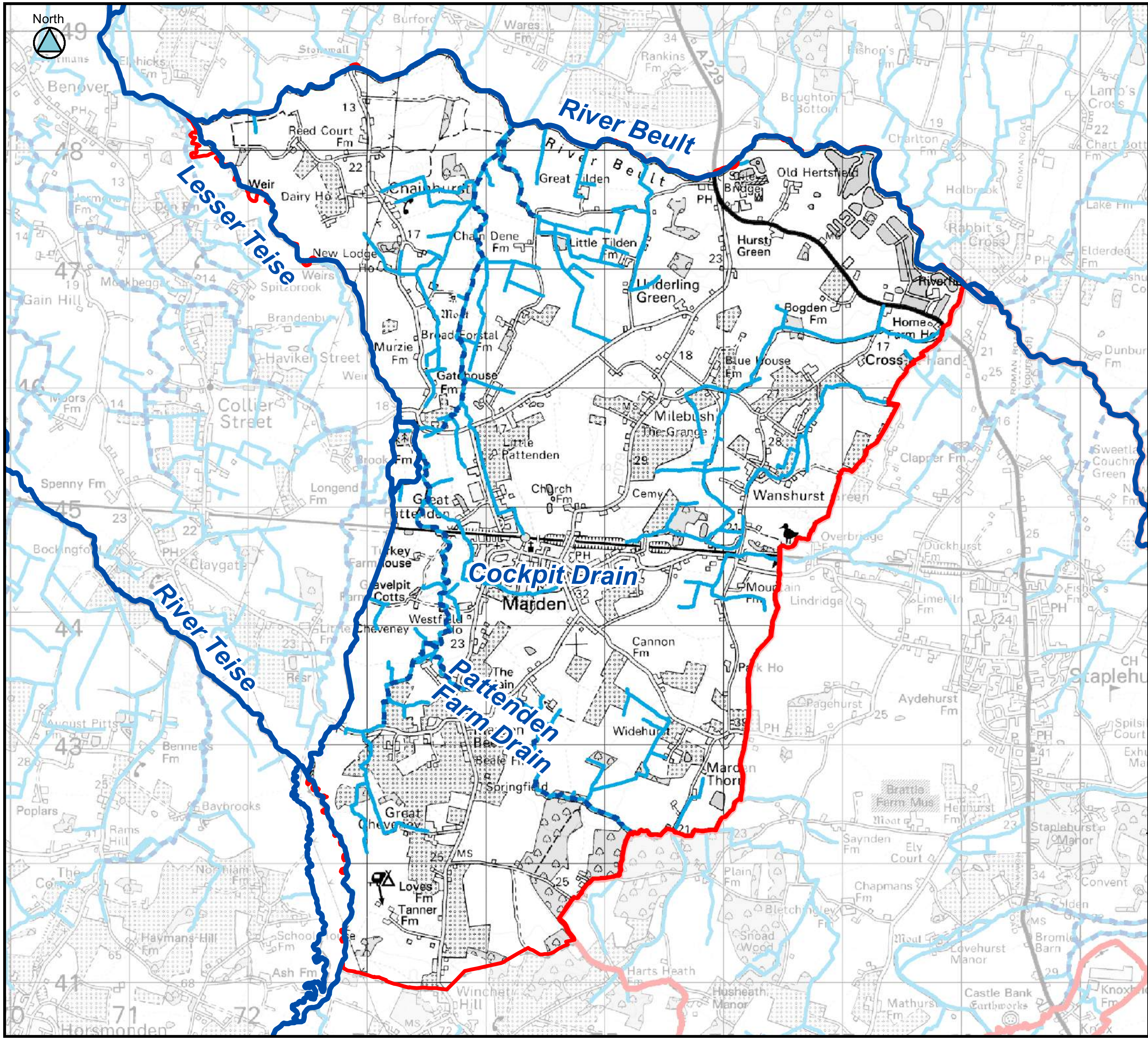
The SWMP Action Plan should be reviewed and updated once every six years as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim, for example:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, which may alter the understanding of risk within the study area;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the Action Plan, and;
- Additional (major) development or other changes in the catchment which may affect the surface water flood risk.

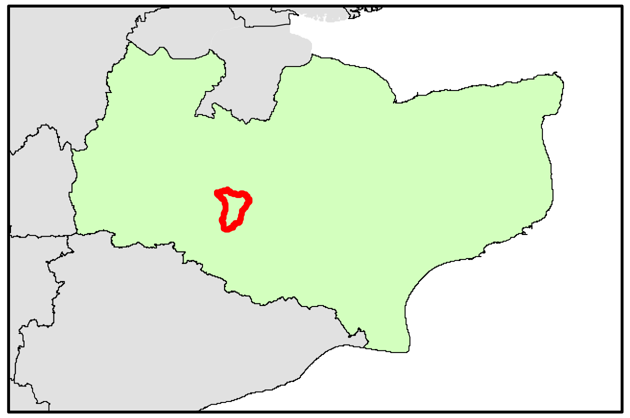
The Action Plan should act as a live document that is updated and amended on a regular basis, and as a minimum this should be as agreed in the Local Flood Risk Management Strategy for Kent, although individual partners may wish to review their actions more regularly.

# Appendices

# A Appendix A - Watercourse Map




## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.

# B Appendix B - Patterns that Lead to Flooding

# NOTE TO FILE

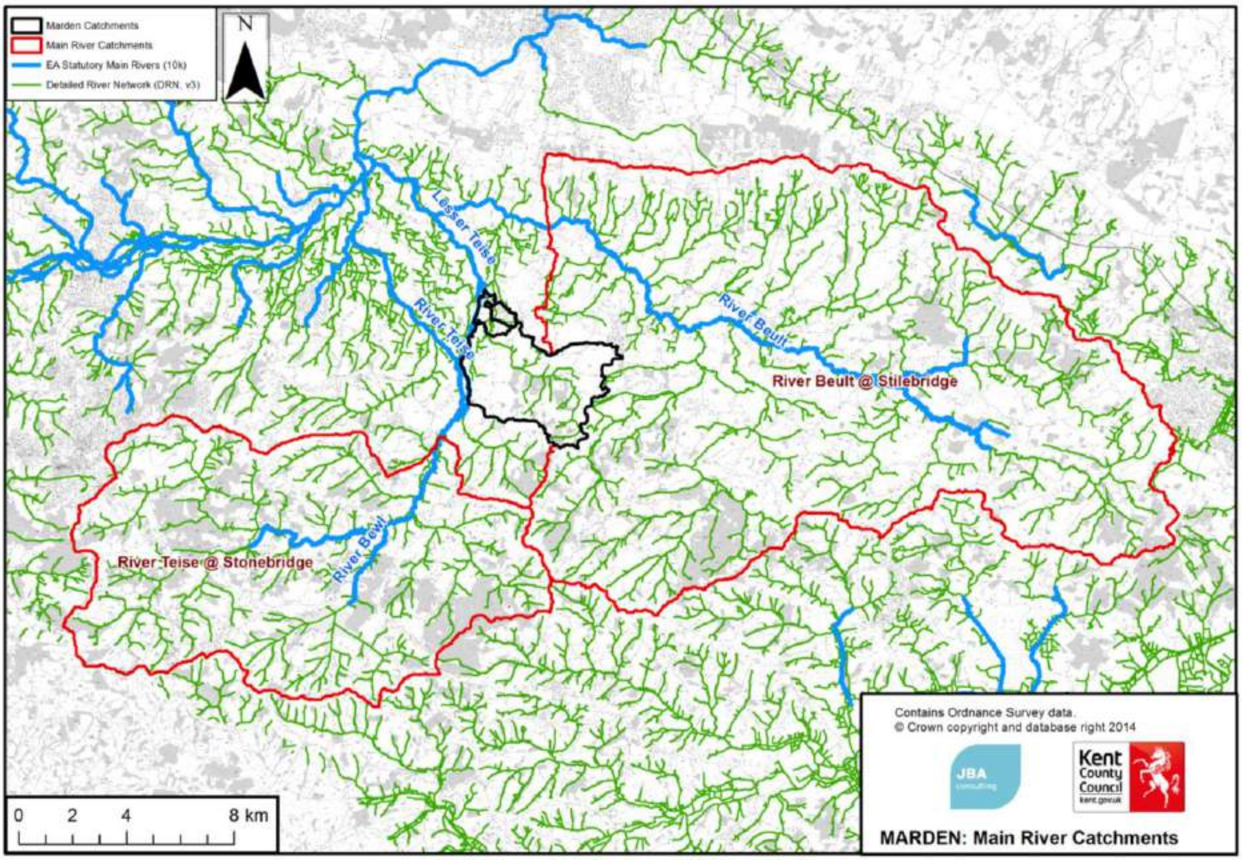
| | |
|---|---|
| JBA Project Code | 2014s1263 |
| Contract | Marden, Staplehurst and Headcorn SWMPs |
| Client | Kent County Council |
| Day, Date and Time | March 2015 |
| Author | Matt Roberts and Jenny Hill |
| Subject | Marden Flood History |

## 1 Introduction

The purpose of this report is to better understand the rainfall events that lead to flooding within Marden in order to determine any potential interactions between adjacent Main River levels (River Beult and River Teise) and the surface water drainage network within Marden.

The village of Marden is located near the topographic boundary between the Lesser Teise and River Beult catchments. The Stilebridge gauging station is located nearly 4km to the north of Marden and the Stonebridge gauging station is located approximately 5km to the south of Marden. Figure 1-1 below illustrates the Marden drain catchments in relation to the gauged catchments at Stilebridge and Stonebridge GS.

**Figure 1-1: Main River catchments**




The majority of the historical flood information available within Marden, Headcorn and Staplehurst is qualitative data i.e. reported flood incidents, highways records, flood hotspots, sources of flooding and occasionally observed flood extents. There are no flow or level gauges within the Marden Drain catchments and therefore Tipping Bucket Raingauges (TBRs) will form the basis of the quantitative assessment of event rarity within Marden. Marden is located within the Lesser Teise catchment which is a tributary of the River Beult. Upstream of Marden (NGR: TQ 72498 42766), the River Teise splits into the lower section of the River Teise and the Lesser Teise catchment.

Surface water flooding events are often as a result of convective summer storms i.e. short intense rainfall events, and therefore 'higher peaked' rainfall profiles would usually be expected if a convective summer event is the main cause of the surface water flooding. These convective summer events also tend to be more critical in urbanised areas.

## 2 Catchment characteristics

The catchments within Marden are underlain predominantly by mudstone deposits (Weald Clay formation) and therefore the catchments are quite impermeable and consequently a more flashy response to rainfall is expected. There are a few outcrops of limestone (Weald Clay formation) to the east of Marden, although these deposits are fairly limited in extent. This is supported by fairly low BFIHOST values in the range of 0.281 to 0.302; the average SPRHOST value is 47%. These geological formations are overlain by superficial deposits of Alluvium and River Terrace deposits which mainly consist of sands, gravel, clays and silts. The superficial deposits are mostly confined to the centre of Marden and along some of the river reaches. The River Teise catchment covers approximately 180km$^2$ to Laddingford and it drains an essentially rural catchment that is underlain with Wealden Group sandstone, siltstone and mudstones overlain by Alluvium and River Terrace deposits along river reaches.

The soils within the Marden catchment predominantly consist of slowly permeable wet clayey soils with impeded drainage. There are freely draining loamy soils to the east of Marden (associated with the Limestone outcrop) but these are fairly limited in extent. Given that Marden is slightly urbanised and the underlying soils and geology and are fairly impermeable, it is likely that Marden is more susceptible to short intense rainfall events. There is a fairly shallow gradient across the catchment with the highest elevation point at approximately 97mAOD (Foxridge Wood) and the lowest elevation point at approximately 15mAOD at the downstream model extent.

## 3 Data availability

There is data available for seven Tipping-Bucket Raingauges (TBRs) in and around Marden, Staplehurst and Headcorn: Staplehurst, Horsmonden STW, Headcorn, Sutton Valance, Charing PS, Bethersden STW and Hollingbourne (Table 3-1 and Figure 3-2). A brief analysis of rainfall data coverage in the catchment was undertaken using Thiessen polygons and the most representative TBRs for the catchment within Marden are Horsmonden STW and Staplehurst TBR.

Table 3-1: Tipping-bucket raingauge information

| Gauge | Altitude (m) | Aspect |
|---|---|---|
| Staplehurst | 19.5 | NE |
| Horsmonden STW | 34.5 | ENE |
| Headcorn | 20.5 | SSE |

*Staplehurst*

The Staplehurst TBR has a slightly shorter record than Horsmonden and rainfall data is only available up until 19th January 2014. The gauge appears to be fairly reliable and compares well with Horsmonden. There are no periods of data flagged as missing but between March 2000 and March 2001 the gauge is recording zero rainfall. There is one potential outlier in May 2003 where 63mm of rain was recorded in 2 hours which was not observed at the other gauges. Staplehurst has quite low annual totals when compared against the other gauges.

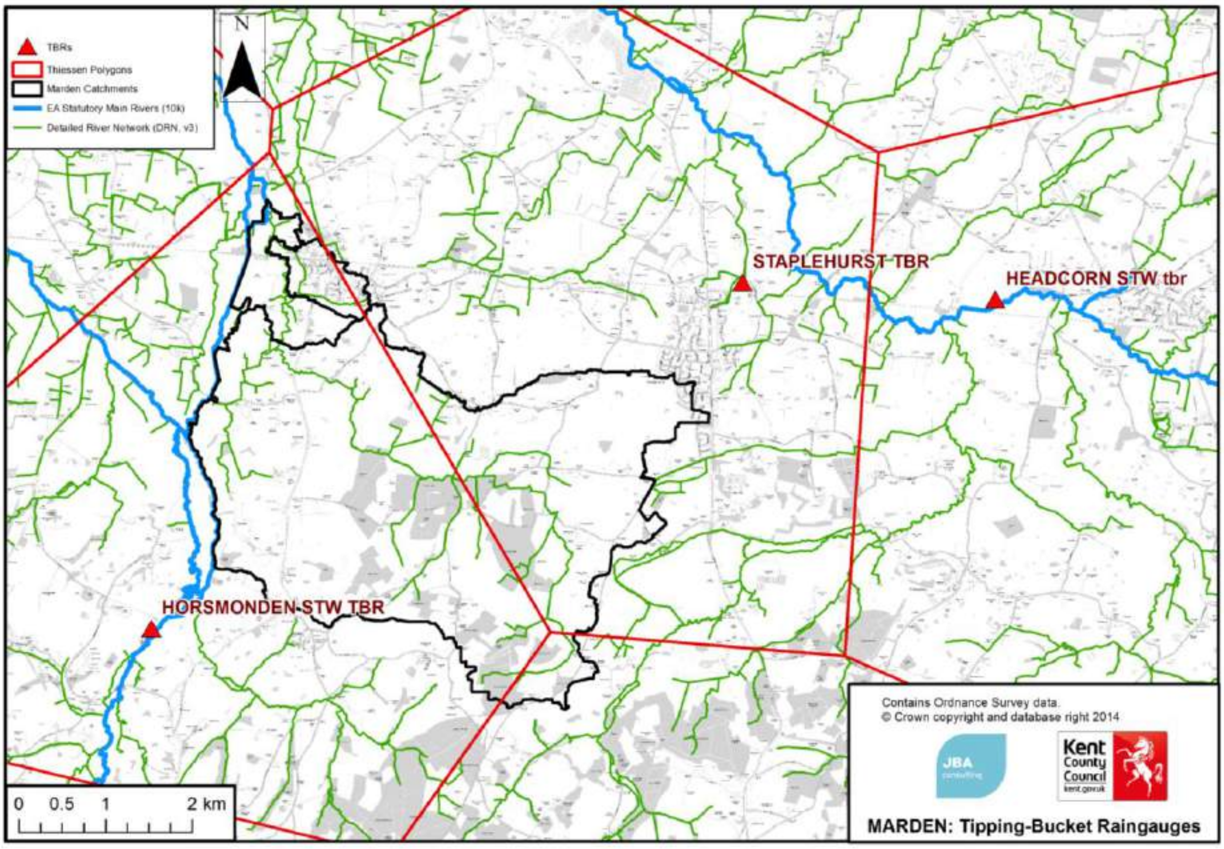
*Horsmonden*

Overall the Horsmonden TBR looks reasonably reliable. There is a period of missing data from November 1996 until July 1997 with another brief gap in August 1997. Between November 2001 and March 2002 the gauge is recording zero rainfall but this has not been flagged as missing. There are no data points associated with unduly high rainfall intensities. The yearly totals from Horsmonden are quite high but appear to match well with a nearby rainfall storage gauge at Pembury. In the earlier years Horsmonden observed 5 to 10% less rainfall than Pembury but in later years (2003 onwards) Horsmonden has been recording slightly more rainfall than Pembury; this may be a result of a recalibration or re-siting of the gauge. The gauge also appears to significantly under record during the October 2000 event.

*Headcorn*

Overall, the Headcorn TBR appears to be good. There are no prolonged periods of missing data. However, the gauge was decommissioned in 2011 and therefore did not record the most recent winter events. As the other two TBRs were either not recording (Staplehurst) or under-recording (Horsmonden) for the Autumn 2000 events, the Headcorn raingauge has been used to determine the rarity of this event.

Figure 3-1: TBR coverage in Marden




## 4 Historical flood events

This section looks at the flood events in Marden as identified during the flood history search.

There are limited reports of flooding within Marden to base this assessment on. However, all of the observed flood events are fairly recent and the source of flooding has also been reported (see Table 4-1).

Table 4-1: Reported flood history within Marden

| Date | Source |
|---|---|
| 2000 (Autumn) | Fluvial |
| February 2009 | Fluvial and Surface Water |
| March 2012 | Surface Water |
| December/January 2013-2014 | Foul Sewer |
| February 2014 | Sewer |

Based on the reported flood events within Marden, it appears as though all of the flood events occur during the winter season (October – March); even the surface water/sewer flood events appear to be during the winter months. Given that the catchments within Marden are generally impermeable and slightly urbanised, it would be expected that Marden would be more susceptible to short intense rainfall events which are typically observed during the summer months. Therefore this suggests that Marden may be more susceptible to flooding based on elevated Main River levels in the River Teise and Lesser Teise which would prevent excess surface water from being cleared from the surface water drainage network i.e. a rise in the water table and nearby Main River levels during periods of higher than normal rainfall may mean that land drainage networks, such as storm sewers, will be unable to discharge excess surface water properly if the water table is higher than normal. Therefore flooding within Marden may be as a result of the inability to discharge excess surface water during Main River flood events.

## 4.1 Rainfall analysis

This section summarises analysis into the return period and duration of rainfall which lead to flooding in Marden.

In order to estimate the order of magnitude of the main flood events within Marden, the same TBR should be used across all of the reported events to enable consistency between return period estimates. Therefore as the rainfall data recorded at the Horsmonden gauge is available up until February 2014, the Horsmonden TBR will be used to assess event rarity for the reported events (Table 4-2). In addition, rainfall totals at Horsmonden correlate well with the local rainfall storage raingauge at Pembury. However, there is a period of missing data during 2000 which means that the October 2000 rainfall event was not recorded at Horsmonden. Therefore, the TBR at Headcorn was used to inform event rarity of the October 2000 event.

Table 4-2: Rainfall analysis

| Date | Rainfall Depth (mm) | Duration (hours) | Rainfall profile | Return Period (years) | Raingauge |
|---|---|---|---|---|---|
| 12/10/2000 | 73.2 | 16.25 | Winter | 35 | Headcorn |
| 10/02/2009 | 34.6 | 24.00 | Mixed profile | 2 | Horsmonden |
| March 2012 | | Non-event; no peak flows observed in the Main Rivers | | | |
| 24/12/2013 | 48.2 | 24.75 | Multi-peak | 6 | Horsmonden |
| January 2014 | | Smaller rainfall totals | | | |
| | *Other peak rainfall events (no significant flooding reported within Marden) – but raised levels in the River Teise at Stonebridge)* | | | | |
| January 2008 | 34.4 | 22.00 | Summer | 2 | Horsmonden |
| December 1999 | 30.4 | 9.00 | Summer | 3 | Horsmonden |

## 4.2 Main River analysis

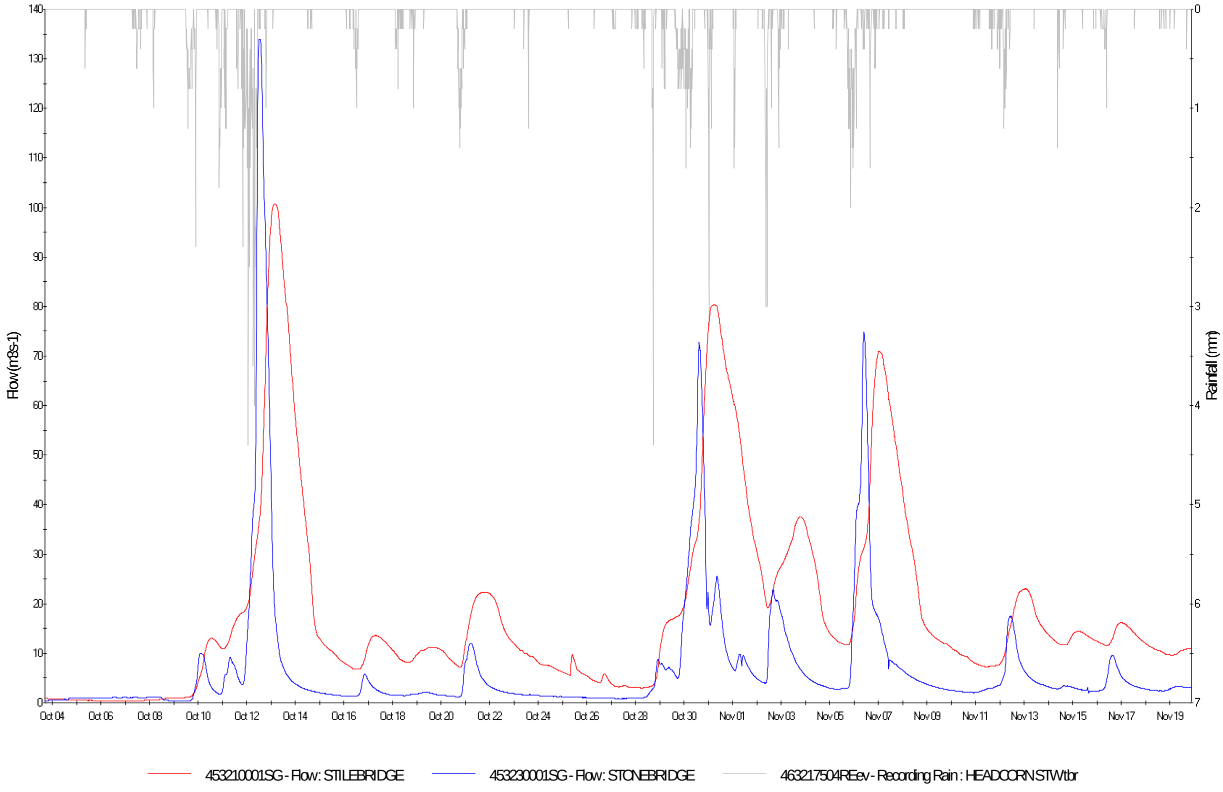
The purpose of this section is to analyse flow patterns on the Main Rivers of the River Beult and Lesser Teise at the time when flood events have occurred in Marden. This analyses will test our hypothesis that local flooding events in Marden, coincide with high water levels on the Main Rivers.

Observed hydrographs for the Stilebridge and Stonebridge gauging stations are shown for each of the reported flood events within Marden. Also included on these hydrometric plots is a continuous rainfall record from nearby representative raingauges (dependent on data availability at the TBRs).

### 4.2.1 Autumn 2000

In autumn 2000, fluvial flooding was reported at Marden. Rainfall recorded at Headcorn STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River Teise at Stonebridge are shown in Figure 4-1.

Figure 4-1: Autumn 2000 events




For the Autumn 2000 events, the River Teise and Beult were characterised by numerous storm events that led to fluvial flooding. The largest peak flows were seen on 12-13 October 2000 (at Stonebridge these were significantly higher than at other times during the winter). Smaller peaks were seen following the storms of 30 October 2000 and 7 November 2000. The Autumn 2000 events (particularly the October 13th event) are the highest ranked events at Stilebridge and Stonebridge.

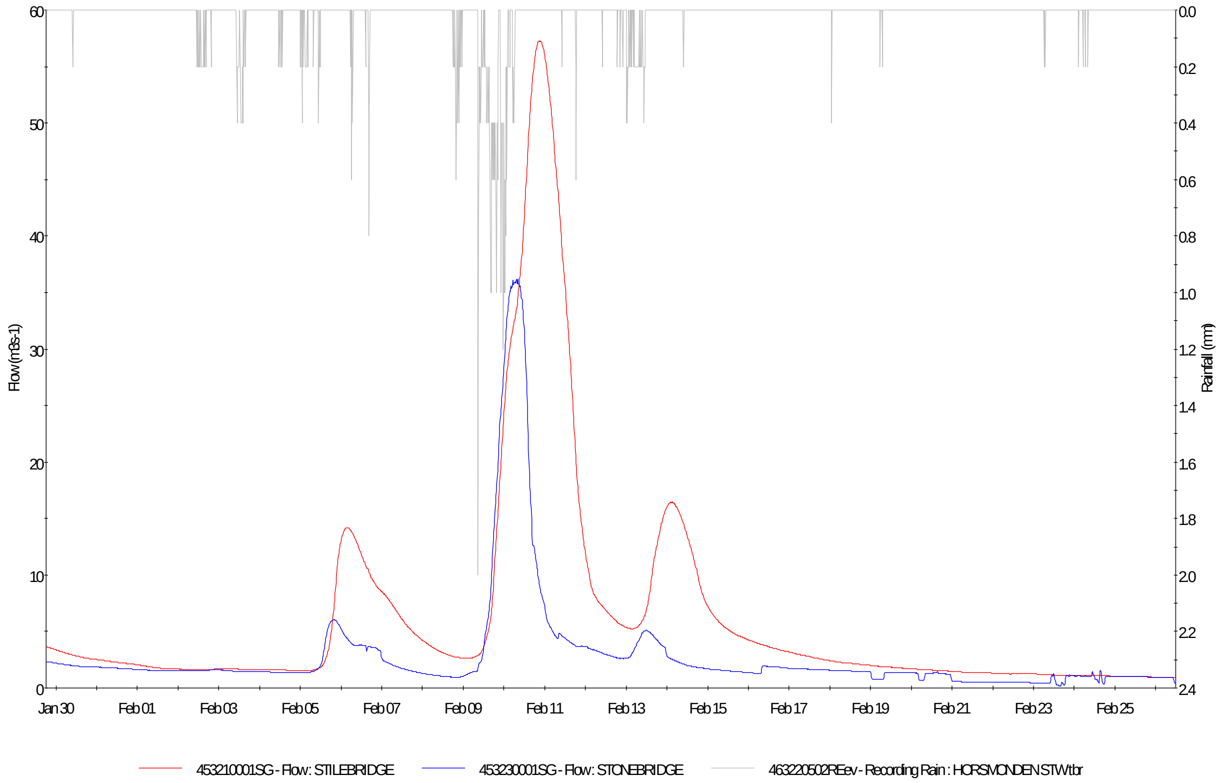
Therefore it is expected that these events were also significant for the Marden Drain catchments. Unfortunately, there is no information on severity or magnitude within the reported flood history in Marden. However, the return period for the rainfall that fell on the 12th October is approximately 35 years.

### 4.2.2 February 2009

In February 2009, fluvial and surface water flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River

Teise at Stonebridge are shown in Figure 4-2.

Figure 4-2: February 2009 event

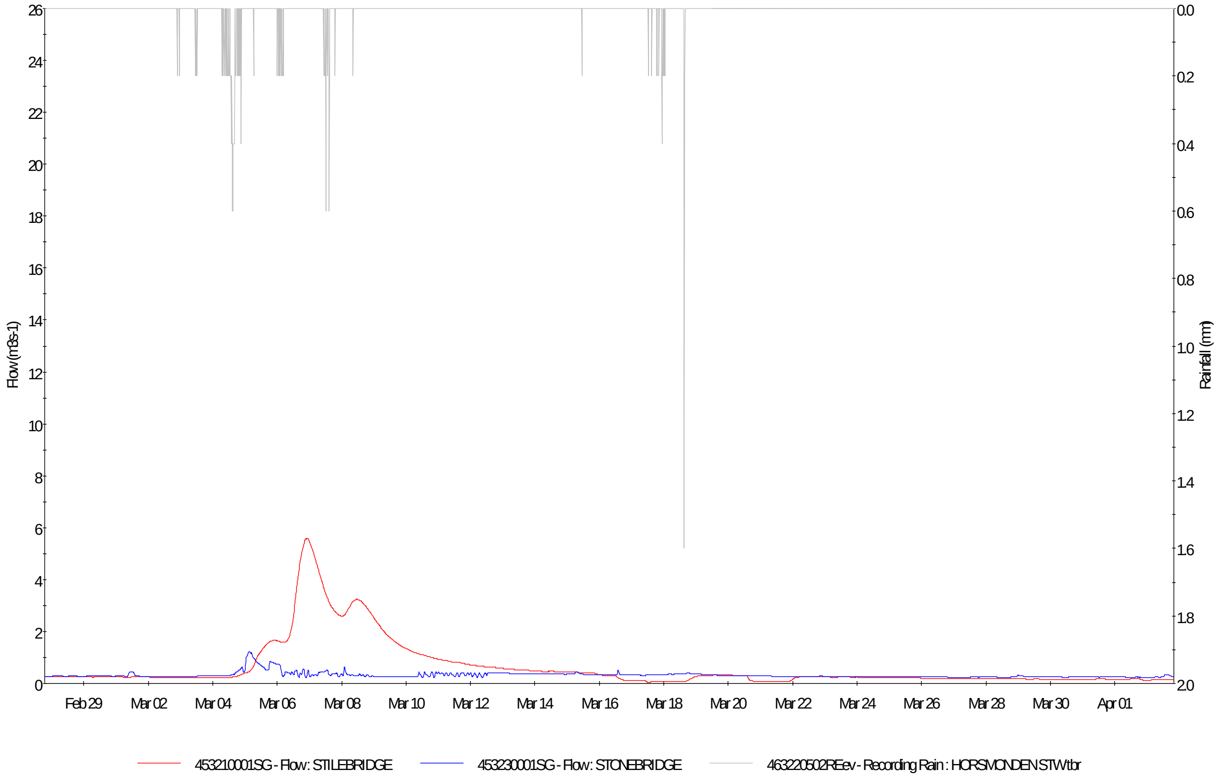



The February 2009 flood event was a result of a period of intense rainfall and levels within the River Beult and Teise rose from approximately 0.5m to 3.2m and 2.3m, respectively. Given the underlying impermeable geology, soil types and urbanised areas within the Marden Drain catchments, it is likely that this intense rainfall event resulted in a combination of fluvial and surface water flooding. This may have also been exacerbated by the elevated Main River levels.

### 4.2.3 March 2012

In March 2012, surface water flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River Teise at Stonebridge are shown in Figure 4-3.

Figure 4-3: March 2012 event

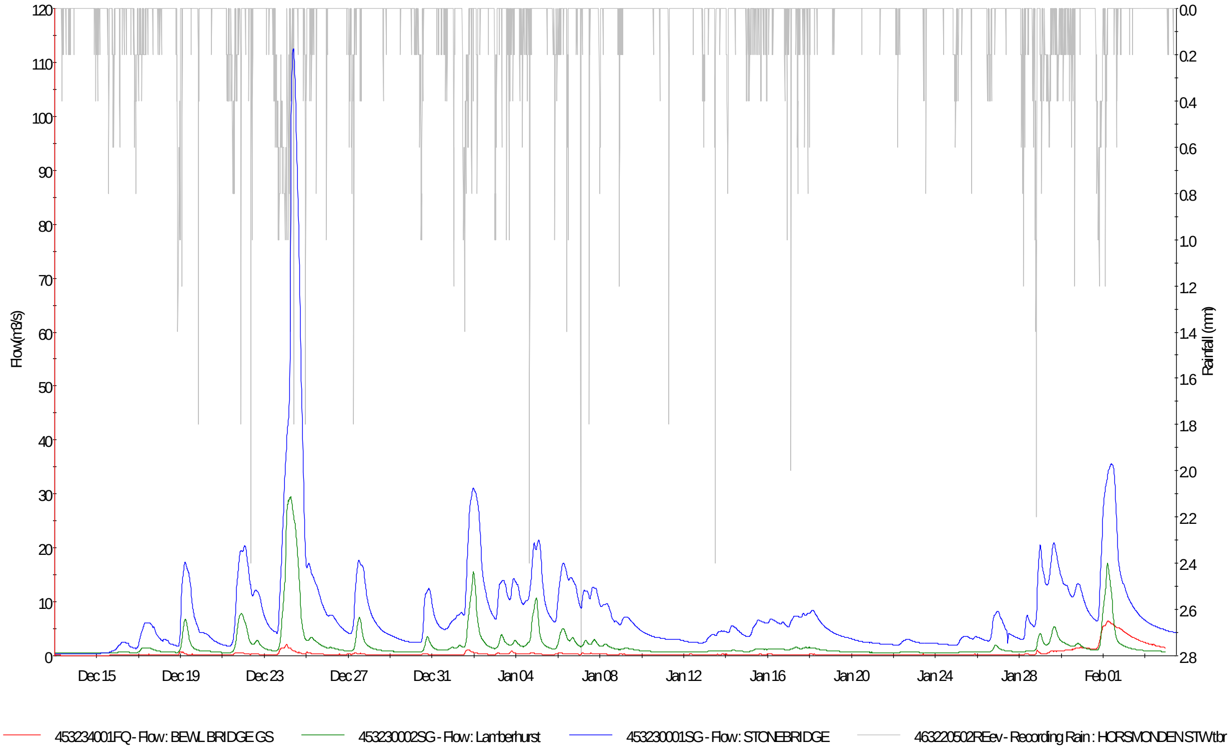



It is likely that this surface water flood event was quite localised and may have been due to a local blockage in the surface water drainage network within Marden. This event has not been included within the analysis.

### 4.2.4 Winter 2013-14

In December 2013 and January 2014, foul sewer flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Teise at Stonebridge, Lamberhurst and Bewlbridge are shown in Figure 4-4.

Figure 4-4: Winter 2013/14 events




For the winter 2013-14 events, the River Teise was characterised by numerous storm events that led to fluvial flooding. The largest peak flows were seen on 24-25 December 2013 (at Stonebridge these were significantly higher than at other times during the winter). Smaller peaks were seen following the storms of 1 January 2014 and 1 February 2014.

The December 2013 event is the second highest ranked event at Stilebridge and Stonebridge. Therefore it is expected that these events were also significant for the Marden Drain catchments. Unfortunately, there is no information on severity or magnitude within the reported flood history in Marden. The return period for the rainfall that fell on the 24th December is approximately 6 years. However, it is expected that the return period of the sustained rainfall totals across December 2013 – January 2014 would be significantly higher.

## 5 Conclusions

The majority of the reported flood events are in the winter months and this therefore suggests that the Marden Drain catchments may be more prone to longer duration frontal rainfall events. However, the Marden catchments are also sensitive to short intense rainfall events due to the underlying impermeable geology and urbanised impervious areas. The reported flood events within Marden are generally associated with elevated Main River levels and high flows in the Lesser Teise and the River Beult. Some of the flood events are as a direct result of sewer or surface water flooding and would therefore most likely be due to short intense rainfall events; therefore these events may not always be observed in the Main Rivers.

However, it is highly likely that the catchments within Marden may be more sensitive to short intense rainfall events during periods when there are elevated Main River levels. This would exacerbate the surface water flooding as the excess surface water is unable to be cleared from the surface water drainage network. Therefore flooding within Marden may be as a result of the inability to discharge excess surface water during Main River flood events.

# C Appendix C - FEH Calculation Record

# Flood estimation calculation record

## Introduction

This calculation record is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 4, 2012). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

## Contents



## Approval

| | Name and qualifications |
|---|---|
| Calculations prepared by: | Matthew Roberts BSc MSc DIC |
| Calculations checked by: | Vicky Shackle BSc PhD MCIWEM C.WEM |

# Abbreviations

AM.................................. Annual Maximum
AREA ............................. Catchment area (km²)
BFI ................................. Base Flow Index
BFIHOST ........................ Base Flow Index derived using the HOST soil classification
CFMP.............................. Catchment Flood Management Plan
CPRE.............................. Council for the Protection of Rural England
FARL............................... FEH index of flood attenuation due to reservoirs and lakes
FEH................................ Flood Estimation Handbook
FSR................................ Flood Studies Report
HOST ............................. Hydrology of Soil Types
NRFA ............................. National River Flow Archive
POT................................ Peaks Over a Threshold
QMED ............................ Median Annual Flood (with return period 2 years)
ReFH ............................. Revitalised Flood Hydrograph method
SAAR ............................. Standard Average Annual Rainfall (mm)
SPR................................ Standard percentage runoff
SPRHOST ...................... Standard percentage runoff derived using the HOST soil classification
Tp(0) .............................. Time to peak of the instantaneous unit hydrograph
URBAN .......................... Flood Studies Report index of fractional urban extent
URBEXT1990 ................. FEH index of fractional urban extent
URBEXT2000 ................. Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH ................. Windows Frequency Analysis Package – used for FEH statistical method

# 1 Method statement

## 1.1 Overview of requirements for flood estimates

| Item | Comments |
|---|---|
| Give an overview which includes:<br>• Purpose of study<br>• Approx. no. of flood estimates required<br>• Peak flows or hydrographs?<br>• Range of return periods and locations | This hydrological assessment was undertaken to inform the Surface Water Management Plan for Marden, Kent. Peak flows are required for the following Annual Exceedance Probability (AEP) events; 50%, 10%, 5%, 3.33%, 2%, 1.33%, 1% and 0.1%. The effects of climate change are to be considered for the 1% AEP event. For this event, flow will be increased by 20% as stated within the FCDPAG3 Economic Appraisal (DEFRA, 2006). |

## 1.2 Overview of catchment

| Item | Comments |
|---|---|
| Brief description of catchment, or reference to section in accompanying report | Marden is a village located approximately 11km south of Maidstone, Kent. The drain catchments within Marden are predominantly covered with Arable (Horticultural) land with a mixture of woodland and grassland. The main built-up area is Marden and part of Staplehurst is located in the upper Marden drain catchment. The total catchment area of the Marden Drains is 17.5km$^2$. A map showing the catchment boundaries is shown in Figure 2-1.<br><br>The catchments within Marden are underlain predominantly by mudstone deposits (Weald Clay formation) and therefore the catchments are quite impermeable and consequently a more flashy response is expected. There are a few outcrops of limestone (Weald Clay formation) to the east of Marden, although these deposits are fairly limited in extent. This is supported by fairly low BFIHOST values in the range of 0.281 to 0.302; the average SPRHOST value is 47%. These geological formations are overlain by superficial deposits of Alluvium and River Terrace deposits which mainly consist of sands, gravel, clays and silts. The superficial deposits are mostly confined to the centre of Marden and along some of the river reaches.<br><br>The soils within the Marden catchment predominantly consist of slowly permeable wet clayey soils with impeded drainage. There are freely draining loamy soils to the east of Marden (associated with the Limestone outcrop) but these are fairly limited in extent.<br><br>There is fairly shallow gradient across the catchment with the highest elevation point at approximately 97mAOD (Foxridge Wood) and the lowest elevation point at approximately 15mAOD at the downstream model extent. |

## 1.3 Source of flood peak data

| | |
|---|---|
| Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made | Yes – Version 3.3.4, August 2014 |

## 1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

| Water-course | Station name | Gauging authority number | NRFA number (used in FEH) | Grid reference | Catch-ment area (km²) | Type (rated / ultrasonic / level…) | Start and end of flow record |
|---|---|---|---|---|---|---|---|
| Ungauged catchment. | | | | | | | |

## 1.5 Data available at each flow gauging station

| Station name | Start and end of data in HiFlows-UK | Update for this study? | Suitable for QMED? | Suitable for pooling? | Data quality check needed? | Other comments on station and flow data quality<br>e.g. information from HiFlows-UK, trends in flood peaks, outliers. |
|---|---|---|---|---|---|---|
| Ungauged catchment. | | | | | | |
| Give link/reference to any further data quality checks carried out | | | N/A | | | |
| **Note** – include plots of flood peak and flood hydrograph data at relevant gauging stations along with interpretation, e.g. in the Annex. | | | | | | |

## 1.6 Rating equations

| Station name | Type of rating<br>e.g. theoretical, empirical; degree of extrapolation | Rating review needed? | Reasons<br>e.g. availability of recent flow gaugings, amount of scatter in the rating. |
|---|---|---|---|
| N/A | | | |
| Give link/reference to any rating reviews carried out | | N/A | |

## 1.7 Other data available and how it has been obtained

| Type of data | Data relevant to this study? | Data available ? | Source of data and licence reference if from EA | Date obtained | Details |
|---|---|---|---|---|---|
| Check flow gaugings (if planned to review ratings) | N/A | | | | |
| Flow data for events | N/A | | | | |
| Results from previous studies | N/A | | | | |

## 1.8 Initial choice of approach

| | |
|---|---|
| Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used. | Yes. The catchments are fairly small but they are quite impermeable and mostly rural. FEH is appropriate as all catchments are > 0.5km² even though the small Marden Drain is not defined on the FEH CD-ROM (v3). The 1% AEP floodplain extents are quite high in the Marden catchments as FPEXT values are generally in excess of 0.21 with the |

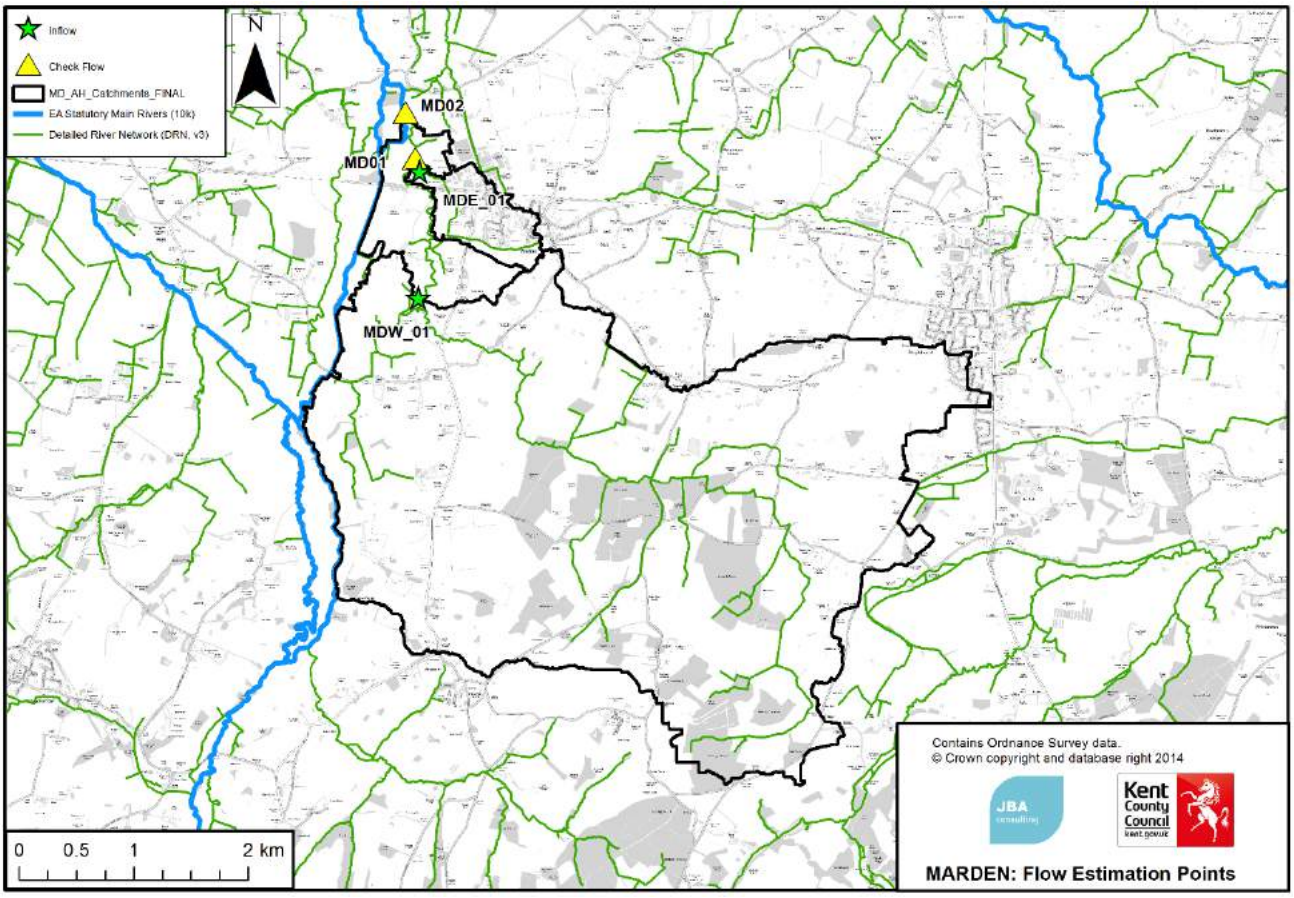
| | |
|---|---|
| | highest FPEXT value being 0.36 i.e. 36% of the catchment being inundated during a 1% AEP event.<br>The small Marden Drain (East) is heavily urbanised and therefore ReFH is not really appropriate. The FEH Statistical method can be applied and the ReFH method could also be applied to provide a comparison with the FEH Statistical estimates as there is no observed flow data to compare against. |
| Outline the conceptual model, addressing questions such as:<br>• Where are the main sites of interest?<br>• What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…)<br>• Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir?<br>• Is there a need to consider temporary debris dams that could collapse? | The main area of interest is the village of Marden which is located south of Maidstone in Kent. The catchments within Marden are likely to be impacted by peak flows due to underlying impermeable geological deposits and also within Marden due to the increase in impervious urbanised area. There is a history of flooding within Marden (see table below). It is unclear whether this flooding is associated with high levels in the adjacent Main River catchments. This will be assessed within the flood history report for Marden which aims to determine catchment response within Marden and whether the flood events are due to insufficient capacity within the drainage network or due to fluvial flooding. This is the main reason for undertaking Direct Rainfall analysis and fluvial analysis to derive a combined fluvial-surface water hydraulic model.<br><br>**Date** / **Source**:<br>2000 (Autumn?) – Fluvial<br>March 2012 – Surface Water<br>December/January 2013-2014 – Foul Sewer<br>February 2014 – Sewer<br>February 2009 – Fluvial and Surface Water |
| Any unusual catchment features to take into account?<br>e.g.<br>• highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20%<br>• highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments<br>• pumped watercourse – consider lowland catchment version of rainfall-runoff method<br>• major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully | The catchments within Marden are quite impermeable (average BFIHOST is 0.29 and SPRHOST is 47%). As the majority of the catchments are essentially rural, both the FEH Statistical and ReFH methods can be used to derive peak flows. |
| Initial choice of method(s) and reasons<br>Will the catchment be split into subcatchments? If so, how? | Both the FEH Statistical and ReFH methods will be used as the catchments are suited to either method and will therefore enable comparison between the two recommended flow estimation methods. Inflows will be derived at the upstream model extents with check flows derived at key locations; confluences and downstream model extent. |
| Software to be used (with version numbers) | FEH CD-ROM v3.0[1]<br>WINFAP-FEH v3.0.002[2] |

| Date | Source |
|---|---|
| 2000 (Autumn?) | Fluvial |
| March 2012 | Surface Water |
| December/January 2013-2014 | Foul Sewer |
| February 2014 | Sewer |
| February 2009 | Fluvial and Surface Water |

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.
[2] WINFAP-FEH v3 © Wallingford Hydro Solutions Limited and NERC (CEH) 2009.

## 2 Locations where flood estimates required

Figure 2-1: Locations of flow estimates




### 2.1 Summary of subject sites

| Site code | Watercourse | Site | Easting | Northing | AREA on FEH CD-ROM (km$^2$) | Revised AREA if altered |
|---|---|---|---|---|---|---|
| MDE_01 | Marden Drain (East) | Upstream model extent of Marden Drain (East) | 573530 | 145047 | N/A | 0.6 |
| MDW_01 | Marden Drain (West) | Upstream model extent of Marden Drain (West) | 573550 | 143800 | 14.2 | 16.0 |
| MD01 | Marden Drains | Confluence of the East and West Drains | 573500 | 145050 | 15.8 | 17.3 |
| MD02 | Marden Drains | Downstream model extent of the Marden Drains. | 573450 | 145450 | 16.0 | 17.5 |
| As there is no gauged data and the geology is fairly consistent across the catchments, the upstream and downstream model extents were selected as the flow estimation points. For the Marden Drain (East), the catchment area derived at the downstream extent was used to inform the model inflow for this catchment as there was no representative catchment at the upstream model extent. | | | | | | |

## 2.2 Important catchment descriptors at each subject site (incorporating any changes made)

| Site code | FARL | PROPWET | BFIHOST | DPLBAR (km) | DPSBAR (m/km) | SAAR (mm) | SPRHOST | URBEXT 1990 | URBEXT 2000 | FPEXT |
|---|---|---|---|---|---|---|---|---|---|---|
| MDE_01 | 0.994 | 0.36 | 0.540 | 0.74 | 10.3 | 650 | 46.69 | 0.1890 | 0.1985 | 0.2301 |
| MDW_01 | 0.997 | 0.36 | 0.281 | 4.22 | 25.8 | 689 | 47.56 | 0.0084 | 0.0090 | 0.2122 |
| MD01 | 0.994 | 0.36 | 0.301 | 5.53 | 24.6 | 686 | 46.69 | 0.0223 | 0.0236 | 0.2301 |
| MD02 | 0.995 | 0.36 | 0.302 | 5.94 | 24.5 | 686 | 46.64 | 0.0222 | 0.0234 | 0.2357 |

Note: Red text denotes catchment descriptor values which have been changed from the FEH CD-ROM values. URBEXT1990 and URBEXT2000 values have been updated to 2014.

## 2.3 Checking catchment descriptors

| | |
|---|---|
| Record how catchment boundary was checked and describe any changes (refer to maps if needed) | The catchment boundaries were checked using 1m resolution DTM data. In the upper catchment, there is a lack of LIDAR coverage and in the absence of any higher resolution data, OS Open Terrain 50k data was used to infer the catchment boundary. In some locations the FEH catchment boundary was amended to take account of the Detailed River Network (DRN v3) so that the rivers do not cut across subcatchment boundaries. The ArcHydro 'rolling ball' analysis tool within ArcGIS was used to define the topographical catchment using a composite elevation dataset which consisted mostly of 1m resolution LIDAR data with some OS Open Terrain 50k data in the upper reaches.<br><br>For the catchments where AREA has changed significantly (>10%), the FEH DPLBAR value was also updated. This is because DPLBAR is based on catchment area and should therefore be updated to reflect the change in area. The standard equation for DPLBAR, given in the FEH Volume 5, uses a power term of 0.548 which is based on research for the UK as a whole. This has been used to update DPLBAR where AREA has changed significantly. |
| Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary. | Soil values (SPRHOST and BFIHOST) were checked against the 1:250,000 Soil Survey of England and Wales map for South East England for both catchments to assess if the FEH CD-ROM values across the study area are reasonable. It was found that the FEH Catchment Descriptors represent the soil types well.<br><br>The urban areas shown on the FEH CD-ROM (v3) were compared against OS 1:50,000 mapping and were deemed to be representative of the study catchment. Therefore the URBEXT values on the FEH-CD ROM (v3) were retained and updated to 2014 values using the CPRE formulae in accordance with the EA Flood Estimation Guidelines.<br><br>The FARL value was checked against the OS mapping for surface water features within the study catchment. There are no major surface water within the Marden drain catchments. Therefore the FARL values from the FEH CD-ROM were used as this corresponds with the OS 1:50,000 Mapping. |
| Source of URBEXT | $URBEXT_{1990}$ has been used for the ReFH method.<br>$URBEXT_{2000}$ has been used for the FEH Statistical method. |

| | |
|---|---|
| Method for updating of URBEXT | $URBEXT_{1990}$ - CPRE formula from FEH Volume 4.<br>$URBEXT_{2000}$ - CPRE formula from 2006 CEH report on $URBEXT_{2000}$. |

# 3 Statistical method

## 3.1 Search for donor sites for QMED (if applicable)

| | |
|---|---|
| Comment on potential donor sites<br>Mention:<br>• Number of potential donor sites available<br>• Distances from subject site<br>• Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors<br>• Quality of flood peak data<br>Include a map if necessary. Note that donor catchments should usually be rural. | A brief assessment of donor stations was carried out for this study using WINFAP-FEH to assess stations that are suitable for QMED within the HiFlows-UK dataset. No suitable donor stations could be located within 40km as the donor catchments were more than 12 times larger than the subject catchment. Therefore QMED estimates were derived using catchment descriptors. |

## 3.2 Donor sites chosen and QMED adjustment factors

| NRFA no. | Reasons for choosing or rejecting | Method (AM or POT) | Adjust-ment for climatic variation? | QMED from flow data (A) | QMED from catchment descriptors (B) | Adjust-ment ratio (A/B) |
|---|---|---|---|---|---|---|
| 40004 | REJECT: The donor catchment is nearly 13 times larger than the subject catchment. SAAR at the donor catchment is approximately 25% higher than the subject catchment and the catchment is located nearly 20km away. The donor catchment also has a slightly higher attenuation due to reservoirs and lakes (FARL=0.975). | AM | N/A | 37.2 | 49.8 | 0.747 |
| 39029 | REJECT: The donor catchment is only 4 times larger than the subject catchment. However, the donor catchment is much more permeable (BFIHOST=0.885) than the subject catchments. SAAR at the donor catchment is approximately 18% higher than the subject catchment and the catchment is located nearly 68km away. The donor catchment also has a much higher attenuation due to reservoirs and lakes (FARL=0.879). | AM | N/A | 2.0 | 1.5 | 1.333 |

| NRFA no. | Reasons for choosing or rejecting | Method (AM or POT) | Adjust-ment for climatic variation? | QMED from flow data (A) | QMED from catchment descriptors (B) | Adjust-ment ratio (A/B) |
|---|---|---|---|---|---|---|
| 41020 | REJECT: As the subject catchment at MDE_01 is very small and urbanised, there are no representative donor catchments. The only donor catchment that is reasonably representative in terms of catchment area is located approximately 47km away. The donor catchment is still over 60 times larger than the subject catchment. However, the donor catchment is much more impermeable (BFIHOST=0.355) than the subject catchments. SAAR at the donor catchment is approximately 36% higher than the subject catchment. Even so, applying this donor would only adjust QMED down by 1%. | AM | N/A | 13.5 | 13.8 | 0.978 |

## 3.3 Overview of estimation of QMED at each subject site

| Site code | Method | Initial estimate of QMEDRURAL ($m^3/s$) | Data transfer | | | | | | Final estimate of QMEDURBAN ($m^3/s$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | NRFA numbers for donor sites used (see 3.3) | Distance between centroids $d_{ij}$ (km) | Power term, a | Moderated QMED adjustment factor, $(A/B)^a$ | If more than one donor: Weight | If more than one donor: Weighted ave. adjustment | |
| MDE_01 | CD | 4.50 | N/A | | | | | | 4.53 |
| MDW_01 | CD | 0.12 | N/A | | | | | | 0.16 |
| MD01 | CD | 4.55 | N/A | | | | | | 4.63 |
| MD02 | CD | 4.60 | N/A | | | | | | 4.69 |

| Are the values of QMED consistent, for example at successive points along the watercourse and at confluences? | Yes, QMED estimates are consistent along successive locations along the same reach. MDW_01 is a separate tributary and the sum of flows upstream of MD02 is greater than the downstream estimate as expected. |
|---|---|

**Important note on urban adjustment**

The method used to adjust QMED for urbanisation, for both subject sites and donor sites, is that published in Kjeldsen (2010)[3] in which PRUAF is calculated from BFIHOST. The result will differ from that of WINFAP-FEH v3.0.003 which does not correctly implement the urban adjustment of Kjeldsen (2010).

[3] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

| Significant differences will occur only on urban catchments that are highly permeable. |
|---|

**Notes**

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below.

The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B)a times the initial estimate from catchment descriptors.

If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

## 3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group. The top three stations within the default pooling group were investigated as these stations will have a greater impact on the growth curve and therefore the final design flow estimates.

| **Name of group** | **Site code from whose descriptors group was derived** | **Subject site treated as gauged? (enhanced single site analysis)** | **Changes made to default pooling group, with reasons**<br>Note also any sites that were investigated but retained in the group. | **Weighted average L-moments,** L-CV and L-skew, (before urban adjustment) |
|---|---|---|---|---|
| MD02 | MD02 | No | <u>Stations investigated</u><br>27073 (Brompton Beck @ Snainton Ings)<br>• Theoretical rating but gaugings show considerable scatter.<br>• Fully contained with no likelihood of drowning. Theoretical rating should apply for the whole range.<br>• Not very representative of the study catchment and variability in the highest AMAX peaks is low (small L-skew) however L-moments are representative of others in the group, although the growth curve is flat there is another site with a similarly shallow growth curve.<br>• As this site is not discordant and fits well with the other stations in the group, the site was retained.<br><br>20002 (West Peffer Burn @ Luffness)<br>• Similar catchment descriptors to the subject site and no observable trend in AMAX series. Mainly impervious catchment which is consistent with the subject catchment.<br>• Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. Therefore this site was retained.<br><br>33054 (Babingly @ Castle Rising)<br>• Subject to drowning. AMAX3 is just above modular limit.<br>• Chalk catchment. Regime influenced by groundwater abstraction / recharge.<br>• AMAX1 and AMAX2 have the same value and occur in water years 1976 and 1978; AMAX 3 is only slightly lower and occurs in water year 1980. | 0.248, 0.093 |

| Name of group | Site code from whose descriptors group was derived | Subject site treated as gauged? (enhanced single site analysis) | **Changes made to default pooling group, with reasons**<br>Note also any sites that were investigated but retained in the group. | **Weighted average L-moments,**<br>L-CV and L-skew, (before urban adjustment) |
|---|---|---|---|---|
| | | | • AMAX values for water years 1983-1986 are almost the same. Similar values for one year following the next: 1994 & 1995, 1997 & 1998, 2002 & 2003.<br>• Some uncertainty in data quality and Chalk not representative of the study catchment but nothing to suggest that retaining this station will skew the growth curve.<br>• Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots.<br><br>Total of 474 years; no stations added as unlikely to improve pooling group. The final pooling group composition can be found within the Annex. | |

**Notes**

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008).

The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

## 3.5 Derivation of flood growth curves at subject sites

The rural growth curve for the pooling group (MD02) is shown in Figure 3-1.

| Site code | Method (SS, P, ESS, J) | If P, ESS or J, name of pooling group | Distribution used and reason for choice | Note any urban adjustment or permeable adjustment | **Parameters of distribution**<br>(location, scale and shape) after adjustments) | Growth factor for 100-year return period |
|---|---|---|---|---|---|---|
| MDE_01 | P | MD02 | Generalised Logistic (GL) distribution selected as GL is the recommended distribution for UK catchments. GEV and P(III) provided the best fit to the data. However, GL provided the most conservative estimates at higher return periods. | Urban adjustment made using v3 method (Kjeldsen, 2010).<br><br>No permeable adjustment – SPRHOST >20%. | 1.000, 0.253, -0.094 | 2.45 |
| MDW_01 | P | MD02 | | | 1.000, 0.225, -0.125 | 2.40 |
| MD01 | P | MD02 | | | 1.000, 0.251, -0.097 | 2.45 |
| MD02 | P | MD02 | | | 1.000, 0.251, -0.097 | 2.45 |

**Notes**

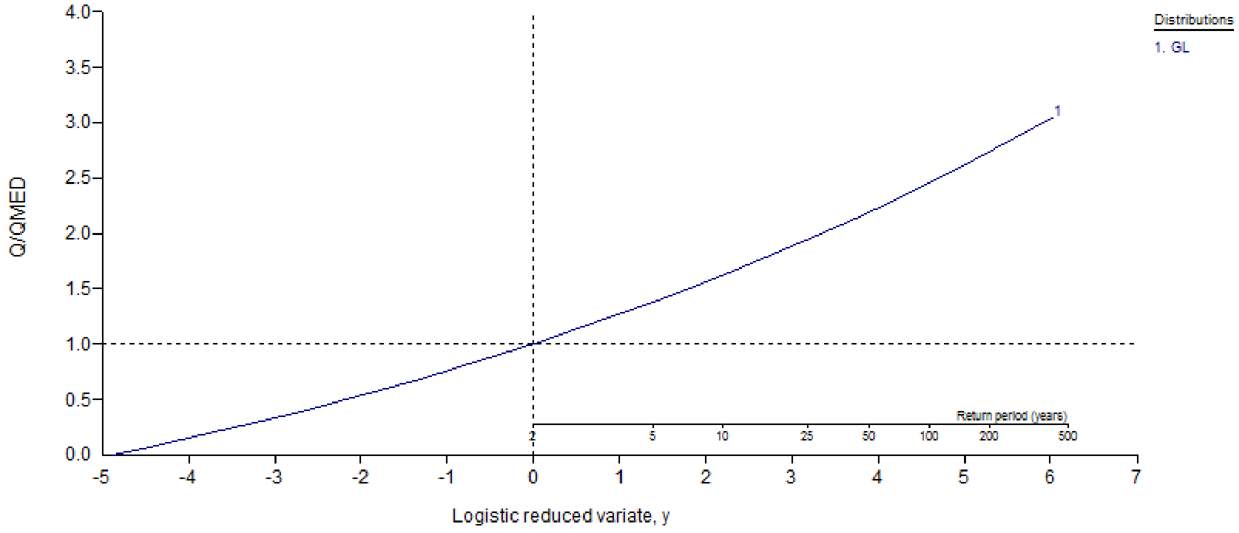
Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the v3 method: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008).

**Figure 3-1: Pooling group growth curve (Rural)**




## 3.6 Flood estimates from the statistical method

| Site code | Flood peak ($m^3/s$) for the following Annual Exceedance Probabilities (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 50 | 10 | 5 | 3.33 | 2 | 1.33 | 1 | 1 (+CC) | 0.1 |
| MDE_01 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 |
| MDW_01 | 4.5 | 7.3 | 8.4 | 9.1 | 9.9 | 10.6 | 11.1 | 13.3 | 15.7 |
| MD01 | 4.6 | 7.5 | 8.6 | 9.3 | 10.1 | 10.8 | 11.3 | 13.6 | 16.0 |
| MD02 | 4.7 | 7.6 | 8.7 | 9.4 | 10.2 | 11.0 | 11.5 | 13.8 | 16.2 |

# 4 Revitalised flood hydrograph (ReFH) method

## 4.1 Parameters for ReFH model

| Site code | Method:<br>OPT: Optimisation<br>BR: Baseflow recession fitting<br>CD: Catchment descriptors<br>DT: Data transfer (give details) | Tp (hours)<br>Time to peak | $C_{max}$ (mm)<br>Maximum storage capacity | BL (hours)<br>Baseflow lag | BR<br>Baseflow recharge |
|---|---|---|---|---|---|
| MDE_01 | CD | 1.203 | 424.637 | 18.881 | 1.335 |
| MDW_01 | CD | 4.426 | 228.304 | 31.841 | 0.659 |
| MD01 | CD | 5.054 | 243.715 | 33.490 | 0.710 |
| MD02 | CD | 5.281 | 244.484 | 34.050 | 0.713 |
| Brief description of any flood event analysis carried out (further details should be given below or in a project report) | | | | | |

## 4.2 Design events for ReFH method

| Site code | Urban or rural | Season of design event (summer or winter) | Storm duration (hours) | Storm area for ARF (if not catchment area) |
|---|---|---|---|---|
| MDE_01 | URBAN | SUMMER | 2.25 | Catchment area |
| MDW_01 | RURAL | WINTER | 7.5 | Catchment area |
| MD01 | RURAL | WINTER | 8.5 | Catchment area |
| MD02 | RURAL | WINTER | 9.5 | Catchment area |
| Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model? | | | The recommended storm duration, based on the standard ReFH equation at the downstream extent is 8.913hrs (with a 0.53-1.06hr data interval). The storm duration and time step used for these estimates are 9.5hr and 0.5hr respectively. The ARF is 0.955 for the 9.5hr duration. These parameters have also been used to derive the hydrograph shape for the FEH Statistical hydrographs.<br><br>A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the downstream location for the hydraulic model. A storm duration of 15.25 hours was found to produce the highest 1% AEP flow estimate at MD02 (ARF=0.962) so therefore this storm duration should be tested within the hydraulic model. As the Marden Drain (East) is a fairly small tributary, it is recommended that the shorter storm duration (2.25hrs) is also tested within the hydraulic model. The standard storm duration at the downstream extent (9.5hrs) will also be tested. | |

## 4.3 Flood estimates from the ReFH method

| Site code | Flood peak ($m^3/s$) for the following Annual Exceedance Probabilities (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 50 | 10 | 5 | 3.33 | 2 | 1.33 | 1 | 1 (+CC) | 0.1 |

| Site code | Flood peak ($m^3$/s) for the following Annual Exceedance Probabilities (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 50 | 10 | 5 | 3.33 | 2 | 1.33 | 1 | 1 (+CC) | 0.1 |
| MDE_01 | 0.2 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 1.6 |
| MDW_01 | 5.8 | 9.4 | 11.2 | 12.2 | 13.9 | 15.3 | 16.4 | 19.7 | 31.5 |
| MD01 | 5.7 | 9.1 | 10.8 | 11.8 | 13.3 | 14.7 | 15.7 | 18.9 | 29.7 |
| MD02 | 5.6 | 9.1 | 10.7 | 11.7 | 13.2 | 14.5 | 15.6 | 18.7 | 29.3 |

# 5 Discussion and summary of results

## 5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

| Site code | Ratio of peak flow to FEH Statistical peak | |
|---|---|---|
| | Return period 2 years | Return period 100 years |
| | ReFH | ReFH |
| MDE_01 | 1.41 | 1.86 |
| MDW_01 | 1.27 | 1.48 |
| MD01 | 1.22 | 1.38 |
| MD02 | 1.20 | 1.36 |

## 5.2 Final choice of method

| | |
|---|---|
| Choice of method and reasons – include reference to type of study, nature of catchment and type of data available. | The FEH Statistical method was chosen due to the consistency of flow estimates downstream and as a result of the Marden Drain (East) catchment being heavily urbanised and small. The ReFH estimates have been provided as a comparison with the FEH Statistical estimates. As hydrographs are required for the hydraulic model, the ReFH hydrograph shapes will be scaled to fit the FEH Statistical peak flow estimates. |

## 5.3 Assumptions, limitations and uncertainty

| | |
|---|---|
| List the main assumptions made (specific to this study) | The main assumptions in this study are that:<br>• The pooling groups is suitably representative of the Marden catchments.<br>• ReFH hydrograph shape is representative of the catchment response; particularly the small urban Marden Drain (East) catchment. |
| Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed | The FEH Statistical method is generally believed to only be suitable for return periods up to 200 years. ReFH is calibrated for return periods up to 150 years. Estimates of flows beyond these return periods are extrapolations and have a higher degree of uncertainty. |
| Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008). | It is not possible to easily assess the uncertainty of the larger flood flow estimates. The FEH allows for calculating confidence intervals for QMED based on catchment descriptors (CDs).<br><br>MDW_01 – QMED: 2.2 – 9.2 ($m^3/s$)<br>MD01 – QMED: 2.3 – 9.5 ($m^3/s$)<br>MD02 – QMED: 2.3 – 9.6 ($m^3/s$)<br><br>Providing 95% confidence intervals for QMED on the urbanised subcatchments (MDE_01) would imply a false level of accuracy in the QMED estimates, given the uncertainty in the UAFs.<br><br>For ungauged catchments it is not possible to consider uncertainty in pooled flow estimates but they are likely to be considerably larger than the uncertainty in QMED. |

| | |
|---|---|
| Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes. | The design flow estimates have been derived for the purposes of this hydrological assessment in order to inform the fluvial component of a Surface Water Management Plan. If peak flow estimates are required for different purposes it is recommended that, at a minimum, a review of results is carried out. |
| Give any other comments on the study, for example suggestions for additional work. | As in most ungauged catchments, it is recommended that temporary flow gauges be installed to better inform the design peak flow estimates. There are no other specific suggestions relevant to this study. |

## 5.4 Checks

| | |
|---|---|
| Are the results consistent, for example at confluences? | Yes, the FEH Statistical peak flow estimates are consistent along reaches and at confluences. |
| What do the results imply regarding the return periods of floods during the period of record? | N/A, ungauged catchments. |
| What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0) | The 1% AEP event growth factors vary between 2.40 and 2.45 which are within the typical range. |
| If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow? | The 0.1% / 1% AEP event ratios vary between 1.41 and 1.45 which are within the typical range (1.3 – 1.8). |
| What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies? | The 1% AEP specific runoff range between 6.5 and 7.0 l/s/ha which are within the typical range (2 – 10 l/s/ha). |
| How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred. | N/A. |
| Are the results compatible with the longer-term flood history? | TBC – will be confirmed against model outputs. There is no gauged data within these catchments to compare the design flow estimates against. |
| Describe any other checks on the results | N/A |

## 5.5 Final results

| Site code | Flood peak ($m^3/s$) for the following Annual Exceedance Probabilities (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 50 | 10 | 5 | 3.33 | 2 | 1.33 | 1 | 1 (+CC) | 0.1 |
| MDE_01 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 |
| MDW_01 | 4.5 | 7.3 | 8.4 | 9.1 | 9.9 | 10.6 | 11.1 | 13.3 | 15.7 |
| MD01 | 4.6 | 7.5 | 8.6 | 9.3 | 10.1 | 10.8 | 11.3 | 13.6 | 16.0 |
| MD02 | 4.7 | 7.6 | 8.7 | 9.4 | 10.2 | 11.0 | 11.5 | 13.8 | 16.2 |

| | |
|---|---|
| If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below) | Flood hydrographs are required for the hydraulic modelling and will be provided in individual ISIS Event Data (.IED) files.<br>A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the |

| | |
|---|---|
| | downstream location for the hydraulic model. A storm duration of 15.25 hours was found to produce the highest 1% AEP flow estimate at MD02 (ARF=0.962) so therefore this storm duration should be tested within the hydraulic model. As the Marden Drain (East) is a fairly small tributary, it is recommended that the shorter storm duration (2.25hrs) is also tested within the hydraulic model. The standard storm duration at the downstream extent (9.5hrs) will also be tested. |

# 6 Annex – supporting information

## 6.1 Pooling group composition

*Table 6-1: Marden Drain (DS) Final Pooling Group*

| Rank | Station Number | Similarity Distance Measure | Years of Data | AREA | QMED AM | L-CV | L-SKEW | Discordancy |
|---|---|---|---|---|---|---|---|---|
| 1 | 27073 | 1.091 | 32 | 8.06 | 0.813 | 0.197 | -0.022 | 0.681 |
| 2 | 20002 | 1.348 | 41 | 26.31 | 3.299 | 0.292 | 0.015 | 1.662 |
| 3 | 33054 | 1.963 | 36 | 48.51 | 1.129 | 0.214 | 0.069 | 0.080 |
| 4 | 203046 | 2.022 | 30 | 22.51 | 10.934 | 0.136 | 0.091 | 1.039 |
| 5 | 41020 | 2.099 | 43 | 35.42 | 13.49 | 0.214 | 0.208 | 1.411 |
| 6 | 33032 | 2.107 | 44 | 56.18 | 0.461 | 0.315 | 0.099 | 1.089 |
| 7 | 72014 | 2.130 | 45 | 28.99 | 17.703 | 0.193 | 0.059 | 0.971 |
| 8 | 34005 | 2.166 | 51 | 72.12 | 3.146 | 0.281 | 0.181 | 0.942 |
| 9 | 73015 | 2.197 | 21 | 30.06 | 12.239 | 0.156 | 0.001 | 0.639 |
| 10 | 26003 | 2.241 | 52 | 59.40 | 1.739 | 0.243 | -0.015 | 0.696 |
| 11 | 36010 | 2.247 | 45 | 27.58 | 6.759 | 0.418 | 0.228 | 1.943 |
| 12 | 26802 | 2.306 | 13 | 15.85 | 0.109 | 0.261 | 0.199 | 0.860 |
| 13 | 36003 | 2.308 | 49 | 56.46 | 3.841 | 0.310 | 0.109 | 0.987 |
| | | | | | | | | |
| | Total | | 502 | | | | | |
| | Weighted | | | | | 0.248 | 0.093 | |

# D Appendix D - Model Operation Manual

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# JBA Project Manager

Jenny Hill

# Revision History

| Revision Ref / Date Issued | Amendments | Issued to |
|---|---|---|
| V1 / August 2016 | | Kent County Council |

Prepared by Chris Matthias BSc MSc

Reviewed by Jennifer Hill BSc MSc

# Purpose

This report provides a record of information required to operate the hydraulic model constructed for the Marden SWMP modelling project.

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# Contents

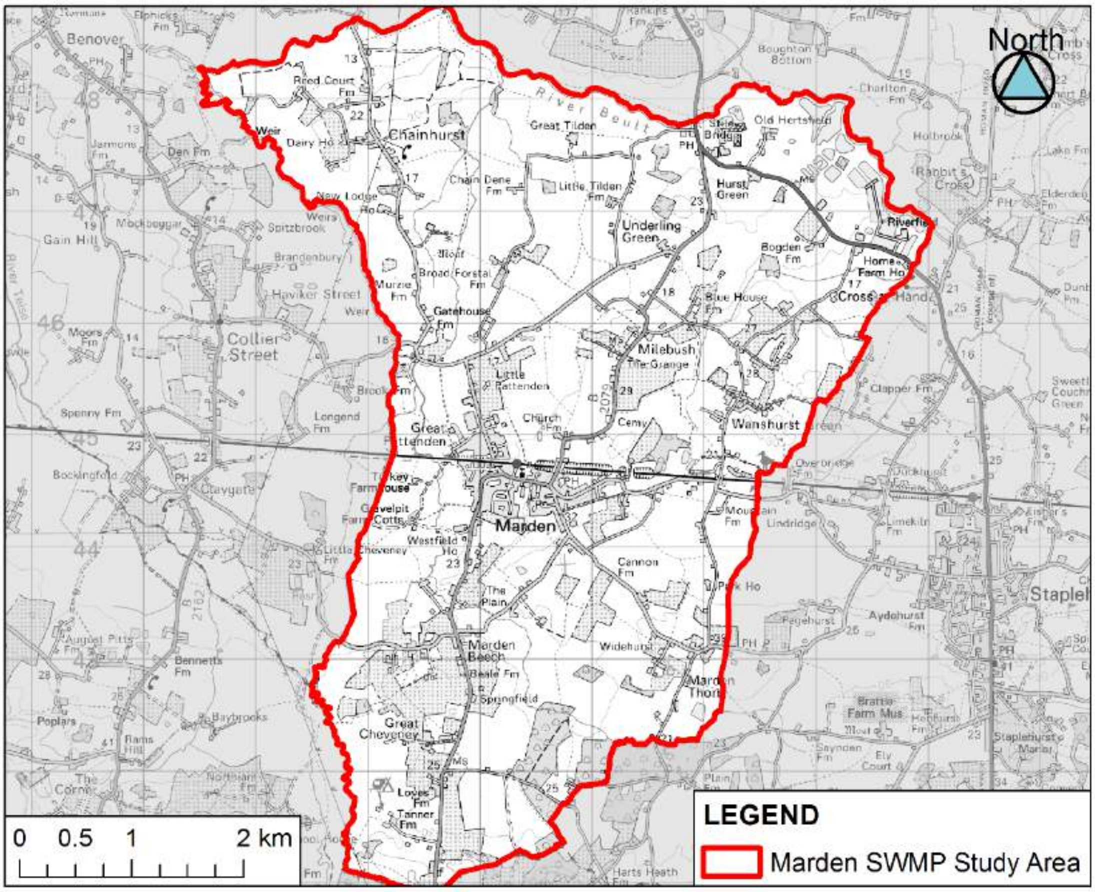
# 1 Model Log

As Lead Local Flood Authority, Kent County Council (KCC) has undertaken a number of Stage 1 Surface Water Management Plans (SWMPs) across Kent to identify areas where more detailed investigations are required. The 2012 Stage 1 SWMP for the Maidstone area identified that the villages of Marden, Staplehurst and Headcorn have a significant local flood risk, with a flood history from surface water to highways and properties. To address this risk, a detailed Surface Water Management Plan in is required for each of the villages with the purpose of producing a 2D hydrodynamic model of the sewers, roads, ground surface and other local water infrastructure that affects the drainage of the parishes.

## 1.1 Study area

The SWMP focuses on the village of Marden within the Maidstone Borough. This area includes the entire parish and is shown in Figure 1-1. This spans north to Chainhurst and south to Winchet Hill.

Figure 1-1: Modelled extent of Marden



# 2 Model build

Marden SWMP required a modelling approach that would simulate the response to rainfall and the interactions with the full drainage arrangement. While historically the different aspects of the urban drainage system have been treated in isolation, the technical tools used to represent and understand drainage systems have begun to allow greater interaction of the river, coastal, above ground, and below ground urban drainage environments. These are relatively new techniques, which are commonly referred to as Integrated Urban Drainage (IUD) modelling approaches. The development of IUD techniques has been partly in response to the floods of 2007 and a number of consultations, including Making Space for Water, Foresight Future Flooding, and the Pitt Review.

For the Marden SWMP modelling InfoWorks ICM was selected. InfoWorks ICM is the most suitable software in this case as it is able to represent the interactions between direct rainfall, overland flows, sewer networks and fluvial systems simultaneously within one modelling platform. It is also the software used by Southern Water and so compatible with their existing models. The software version was InfoWorks ICM 6 which was the latest available version.

## 2.1 Available data

This section outlines the data used to inform the Marden SWMP modelling project.

### 2.1.1 Surveys

To support this and previous studies of Marden, a number of surveys have been undertaken which are relevant to the SWMP. These are listed in Table 2-1.

Table 2-1: Surveys in the Marden relevant to the SWMP

| Survey | Date | Description |
|---|---|---|
| Watercourse survey - KCC | January 2014 | Topographic survey of river cross sections and structures |
| Highway drainage survey - KCC | February 2015 | Asset documentation of highway gullies and connected pipework |
| Lidar topographic survey - Environment Agency | 2009 | 1m resolution elevation data covering 100% of Marden |
| Lidar topographic survey - Environment Agency | 2002 | 2m resolution elevation data covering an additional 100% of Marden |

These surveys have been used as a basis for the existing models (outlined in Section 2.1.2) and referenced though out the model development (explained in Section 2.2).

### 2.1.2 Existing models

Southern Water held an existing sewer model for Horsmonden which includes Marden. This model included the foul and combined drainage. This model was built and verified in InfoWorks-CS. The model was migrated to InfoWorks ICM and included in the Marden SWMP model.

### 2.1.3 Asset data

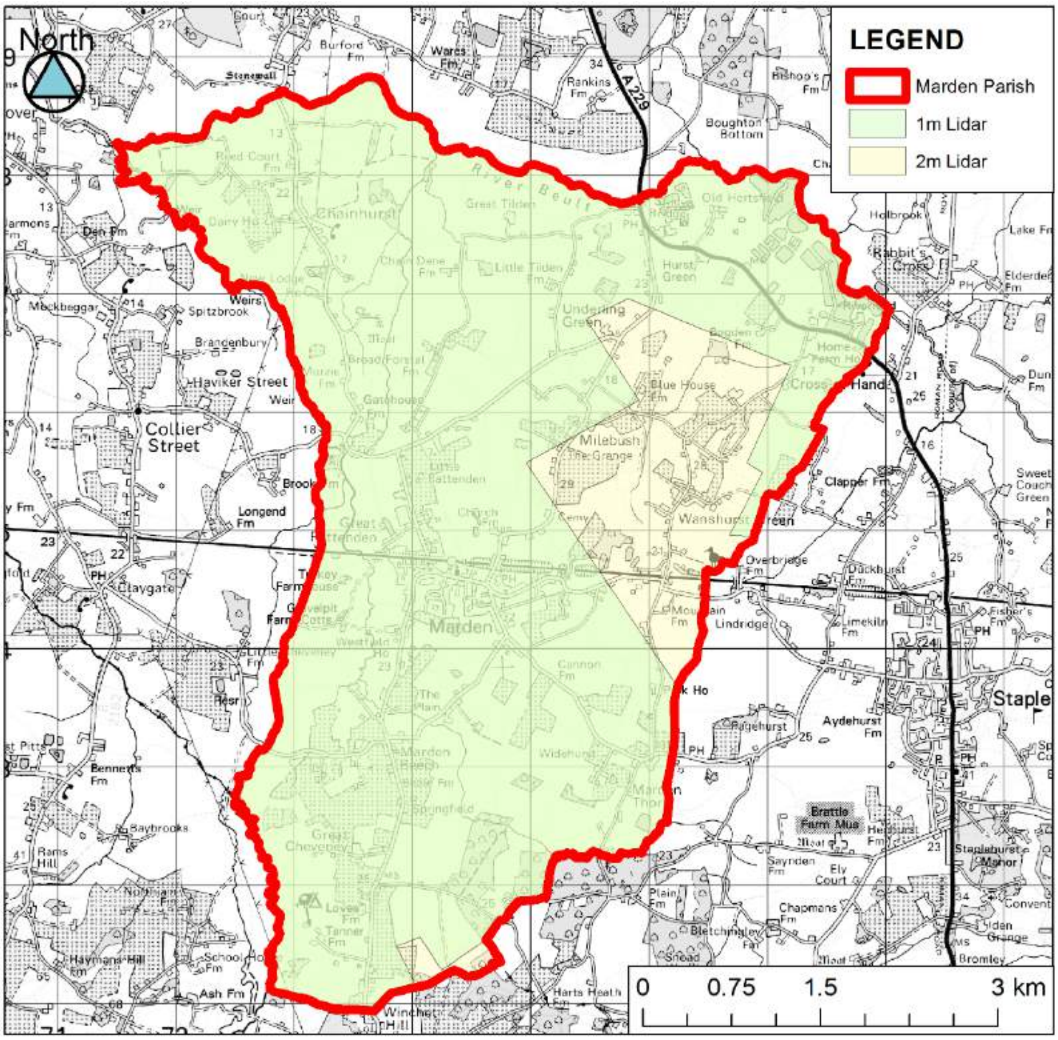
In addition to the DAP model, Southern Water also provided an Impermeable Area Survey which had been used in the development of the DAP model to understand what areas are positively drained to the sewerage system.

Kent County Council keep a GIS record of their gully pots which documents the type of gully and its condition during the last inspection. This database does not include details on the piped network, which is why KCC commissioned further surveys to provide this information.

### 2.1.4 Topographic data

Lidar data was no available across the study area and was supplemented by photogrammetric elevation data collected by KCC. The 85% of the study area is covered with one metre resolution data as shown in Figure 2-1. Where one metre Lidar data was not available, two metre resolution Lidar data has been used to fill the gaps. The DTM data were mosaicked into one DTM surface at a one metre resolution to preserve the detail of the better quality data.

Figure 2-1: DTM resolution coverage across the Marden study area




### 2.1.5 Land use data

Kent County Council have provided Ordnance Survey Master Map data to support the project. This has been used in the model to define where surfaces are manmade, natural or multiple (such as gardens). The Master Map has also been used to inform building foot prints and surface roughness's.

## 2.2 Model development

The Marden model has been based on the Southern Water DAP model, which is 1D only. However, as the purpose of these models is different, model development was required to meet the objectives of the Marden SWMP study. Most significantly, this included;

- adding a 2D domain to understand surface routing of sewer exceedance and pluvial runoff and developing the 1D model so it is compatible with 2D modelling;
- adding the ordinary watercourse and IDB drains to the model;
- adding highway gullies to the sewerage model; and
- representing the Main Rivers using downstream conditions.

### 2.2.1 2D model

The development of a 2D model is outlined in Table 2-2.

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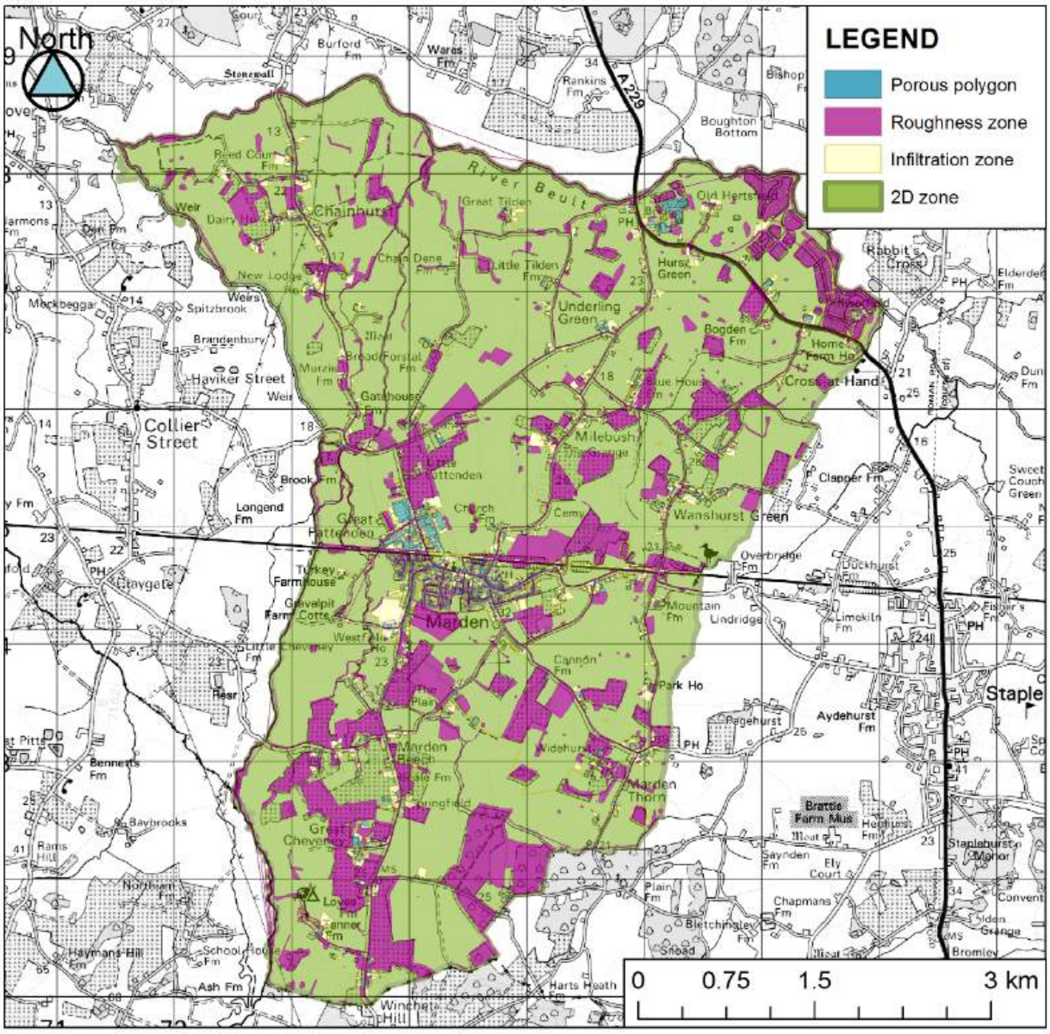
Table 2-2: 2D model development

| Physical Feature | Model Feature | Count | Description |
|---|---|---|---|
| Topography | 2D zone | 1 | The 2D zone was the whole parish and surrounding areas which would drain in.<br>The 2D zone was divided into a mesh of elements.<br>Each element took its elevation from the DTM<br>The elements varied in size between 25 and 1 $m^2$<br>The roughness, infiltration and porosity of each element was set by overlying zones<br>Rainfall was applied outside of subcatchments |
| | Mesh Zone | 1 | The village centre is covered by a mesh zone to create a more detailed mesh in this location. This is to better represent local changes in topography.<br>The elements varied in size between 10 and 1 $m^2$ |
| Land cover | Roughness zones | 2107 | The roughness zones were imported from Master Map<br>Each land surface has its own roughness<br>Structure/ building = 0.3<br>Parkland/ garden = 0.03 - 0.04<br>Roads/ pavements = 0.02<br>Water = 0.035 |
| Buildings | Porous polygons | 2832 | The porous polygons were imported from Master Map<br>The polygons were merged and their geometry simplified as the boundary of polygons are used as break lines in the mesh.<br>The porosity of each building was set to 0.05 - allowing 5% of flows through the building.<br>There was no crest level set (as water depth would not exceed roof height) so the buildings were infinitely tall |
| Roads | Break lines | 80 | Breaklines force the mesh to generate triangles along its edge, which ensures that the areas near to the breakline have well defined linear features. Breaklines have been used within the models to define the edges of roads where road kerbs help to direct and contain shallow surface water flows.<br>The breaklines used to model the roads were generated using OS MasterMap data. |
| Rainfall losses | Infiltration zones | 9853 | The infiltration zones were imported from Master Map<br>Two runoff surfaces have been used according to land use and soil type<br>Impermeable land uses have a fixed runoff rate (using the Fixed model). |

| Physical Feature | Model Feature | Count | Description |
|---|---|---|---|
| | | | • Low density residential = 80%<br>Permeable land uses have a time varying runoff rate (using the Horton model)<br>• Rural areas inside soil WRAP class 4 = 44 mm/hr initial and 1 mm/hr limiting |

Figure 2-2 shows the 2D model schematic although it should be noted that some pf the infiltration zones overly roughness zones, so not all the roughness zones are shown in this diagram.

Figure 2-2: Marden 2D model schematic




## 2.2.2 1D model

The developments to Southern Waters DAP model have been summarised in Table 2-3.

Table 2-3: 1D model development

| Feature | Description | Development | Justification |
|---|---|---|---|
| River reach | Create ordinary watercourse and IDB drains model | Import survey data to the model and convert to river reaches linked to the 2D domain. Apply inflow and DS condition. | Understand flooding from watercourses, backing up and discharge limitations of SW systems |
| Watercourse structures | Create bridges, culverts and sluices | Use survey data to construct structures, including inlets/ outlets and spills | Represent contraction caused by structures. |

| Feature | Description | Development | Justification |
|---|---|---|---|
| Surface Water sewers | Create sewers from asset data | Use Southern Water data to build surface water sewer model | Represent rainfall lost to sewers and sewer flooding. |
| Subcatchments | Define areas contributing to surface water | Create subcatchments geometry to areas of manmade / multiple land use which would drain to sewers | Applies flows to the 1D sewer model |
| Subcatchments | Define areas contributing to foul sewers | Shrunk foul subcatchments to circles with 1m diameter. No change to population. | Prevent foul subcatchments limiting overland runoff generation. |
| Inlet 2D | Represent highway drainage gullies | Inlet 2D nodes added to the model to represent KCC gullies. | Represent overland flow accessing sewerage. Allow 1D 2D connectivity. |
| Highway drainage sewers | Piped connections between gullies to SW sewer or drainage ditch. | Build pipe connection from KCC survey were available. Some assumptions required where data was missing. | Allow discharge of highway gullies. |
| Manholes | Represent sewer manholes | Set flooding manholes from 'lost' flood type to '2D' flood type | Allow flooding out on to the mesh |

### Subcatchments

The surface water catchments for each drainage area was delineated into a number of sub catchments in order facilitate flows into the surface water network. These predominately represented the roofs of the buildings within the drainage areas. Each of the sub-catchments has a defined unit hydrograph, which is representative of an urban catchment with user defined Time to peak values. Open areas such as parks, gardens and areas within the topographic catchment but outside of the drainage network were modelled using direct rainfall as this was considered a more suitable approach for these areas.

### Runoff surfaces

All sub-catchments in Marden were less than 2.5 Ha therefore there was no requirement to use large sub-catchment routing models.

Table 2-4: Runoff zone parameters

| Runoff Surface ID | Runoff Routing Value | Runoff Volume Type | Surface Type | Initial Loss Type | Routing Model | Runoff Coefficient | New UK Depth |
|---|---|---|---|---|---|---|---|
| 10 | 1 | Fixed | Impervious | Slope | Wallingford | 0.75 | - |
| 20 | 1 | Fixed | Impervious | Slope | Wallingford | 0.75 | - |
| 21 | 4 | New UK | Pervious | Abs | Wallingford | - | 0.1 |

Each land use class was assigned a runoff zone for one of three runoff surfaces, which were defined as follows:

- Runoff surface 1 - Roads and Pavements (ID - 10)
- Runoff surface 2 - Building roofs (ID - 20)
- Runoff surface 3 - Permeable areas (ID - 21)

The runoff surfaces within each of the sub-catchments were defined using the MasterMap land use types which were used to calculate the absolute areas of runoff within each sub-catchment.

## 2.2.3 1D 2D connectivity

The 1D and 2D models were connected at selected manholes and along the banks of the modelled river reach. The manholes where connected to the 2D zone using a 2D flood type. Only a selection of manholes where connected to prevent and unrealistic amount of surface water draining to the sewers. Instead the manholes predicted to flood where set to 2D. As a result, the exceedance flows were able to route across the 2D zone.

### 2.2.4 Boundary conditions

There are several outfalls from the surface water network into Cockpit Drain at Marden. Outfall locations include The Cockpit, Goudhurst Lane, Sovereigns Way and the Wheelbarrow Estate. At these locations, the sewer network model has been dynamically connected to the Cockpit Drain to allow fluvial backing up (where flap valves allow).

## 2.3 Model overview

A summary of the modelled features is listed in Table 2-5.

Table 2-5: Features included in the Marden model

| River | Channel (km) |
|---|---|
| Cockpit Drain | 3 |

| Sewers | Nodes | Pipes (km) |
|---|---|---|
| Surface Water System | 309 | 5.5 |
| Foul System | 663 | 35.8 |

| Roughness Zone | Porous Polygon | Infiltration Zones |
|---|---|---|
| 1,262 | 2,076 | 6,455 |

# 3 File structure

Table 3-1: Marden model file structure

| Item |
|---|
| Compact Transportable Database |
| Model Runs |
| Marden Direct Rainfall Runs |
| Marden Design Runs v6 100yr 9.5 hr! |
| Marden Design Runs v6 1000yr 9.5 hr |
| Marden Design Runs v6 20yr 9.5 hr! |
| Marden Design Runs v6 50yr 9.5 hr |
| Marden Design Runs v6 75yr 9.5 hr |
| Marden Design Runs v6 30yr 9.5 hr |
| Marden Design Runs v6 10yr 9.5 hr |
| Level Group |
| Marden Level Group |
| Marden DS 20% AEP |
| Inflows |
| Marden IDB watercourse |
| 100yr 9.25 hr |
| 1000yr 9.25 hr |
| 20yr 9.25 hr |
| 50yr 9.25 hr |
| 75yr 9.25 hr |
| 30yr 9.25 hr |
| 10yr 9.25 hr |
| Marden, Staplehurst and Headcorn Parishes |
| Marden! |
| Initial condition group |
| Marden 75% catchment wetness |
| Rainfall |
| Marden Rainfall |
| 100 Year 9.25 mm/hr |
| 1000 Year 9.25 hr v2 |
| 20 Year 9.25 mm/hr |
| 50 Year 9.25 hr v2 |
| 75 Year 9.25 hr v2 |
| 30 Year 9.25 hr v2 |
| 10 Year 9.25 hr v2 |
| Recycle Bin |

| Model Folder | Content | Description |
|---|---|---|
| Network Group | Marden! | Network used for design runs (scenarios include flood alleviation options) |
| Ground model grid group | LIDAR_Kent_v4 | ASCII composite of 1 & 2m Lidar data |
| Rainfall | 100 Year 9.25 mm/hr<br>1000 Year 9.25 mm/hr<br>20 Year 9.25 mm/hr<br>50 Year 9.25 mm/hr<br>75 Year 9.25 mm/hr<br>30 Year 9.25 mm/hr<br>10 Year 9.25 mm/hr | ReFH rainfall hyetographs.<br>555-minute storm - judged the critical duration<br>No losses applied except seasonal correction factor and aerial reduction factor.<br>Losses to infiltration applied in the model. |
| Inflows\ Marden IDB watercourse | 100yr 9.25 hr<br>1000yr 9.25 hr<br>20yr 9.25 hr<br>50yr 9.25 hr<br>75yr 9.25 hr<br>30yr 9.25 hr<br>10yr 9.25 hr | ReFH hydrograph fitted to a FEH Stats peak for the Patternden Farm Drain through Marden. |
| Level group | Marden DS 20% AEP | Hydro-static water level representing peak of 5yr storm (lowest return period modelled by EA Medway study). |
| Initial conditions group | Marden 75% catchment wetness | 75 % catchment wetness |
| Run groups | Marden Direct Rainfall Runs | Final design runs and option tests |

# 4 Model Verification

The performance of the Marden model has been tested against two data sets. The first is flood records collected from the project partners, including a mapping workshop and the second is ReFH check flows calculated by the hydrology.

## 4.1 Historic verification

Information on flood incidents in Marden was collected from Kent County Council, Southern Water and Marden Parish Council. These recorded incidents have been used to check the model performance.

Locations where pluvial runoff have been reported have been well represented by the IUD model, with Howland Road, Goudhurst Road, Pattenden Lane and the Cockpit all predicting flooding where pluvial runoff has been reported. However, surface water runoff is also predicted on Park Road and Thorn Road which has not been reported. Flooding from surface water when drainage was blocked has been reported on Stanley Road and Maidstone Road which is not predicted by the IUD model. In the model as it is assumed that all assets are free of obstruction, therefore it is possible the surface water flooding at these locations could be avoided if the drainage network was running clear.

## 4.2 Model workshop

The baseline model results were presented to the project steering group for their approval based on local knowledge of flood mechanisms. This meeting found that the flood extents predicted at Howland Road and Goudhurst Road matched well with flood extents observed in the winter of 2013/2014. However, the flooding at the Wheelbarrow Estate under predicted what was observed.

This led to testing of downstream boundaries on the model and the understand that flooding at the Wheelbarrow Estate is driven by the Lesser Teise rather than the Cockpit Drain or Patternden Farm Drain. The final model uses a downstream boundary which represented peak water level on the Lesser Teise during a 20% AEP event. The event was selected as it was the smallest event modelled as part of the Medway modelling and mapping study (Environment Agency 2015). This restricted discharge of ordinary watercourses and surface water drainage systems increased the frequency of flooding in line with observed events.

A further model amendment was made following the workshop to alter the runoff rate from rural areas from fixed runoff (using SPRHOST to dictate the runoff rate) to variable runoff using the Horton model. This was because the longer storm duration of seven hours was found to be critical and increasing soil saturation and therefore increased runoff can be expected in a storm of this length. The variable runoff rate increased the surface water generated in the rural parish.

## 4.3 FEH Statistical method check flows

At hydraulic model testing stage, the use of the direct rainfall to calculate fluvial flows on the Cockpit Drain was tested against FEH Statistical flow estimates. The results of this comparison after the model changes listed above including application of a downstream boundary and using a variable runoff rate from rural areas are shown in Table 4-1.

Table 4-1: Comparison of FEH Stats and modelled flows on Cockpit Drain

| Method | Flood peak ($m^3/s$) for the following AEP (%) events | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50 | 10 | 5 | 3.33 | 2 | 1.33 | 1 | 0.1 |
| FEH Stats | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 |
| Modelled | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.6 |

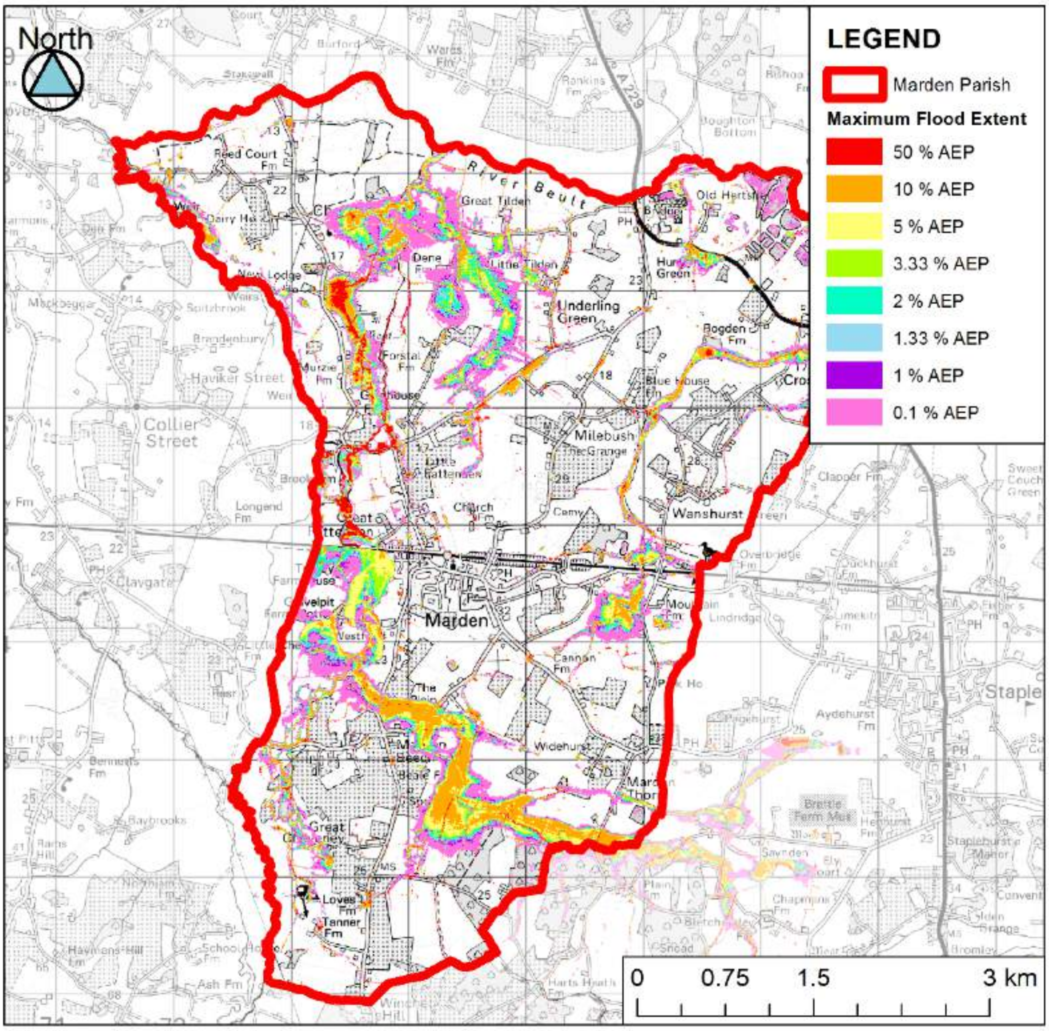
The testing concluded that the modelled flows derived from direct rainfall were a good match for the FEH flows. There are always inherent uncertainties in hydrology but two methods agreeing peak flows increased overall confidence. It should be noted that the modelled peak flow across the length of the Cockpit Drain was shown to increase by 25% through the modelled reach. This indicates that a direct rainfall, which distributes inflow throughout the length, is more appropriate than a single lumped FEH inflow.

# 5 Model results

## 5.1 Baseline model

The maximum flood extent predicted for design storms is shown in Figure 5-1.

Figure 5-1: Maximum extent of design storms




The outlines show the village of Marden is generally at low risk of flooding. The greatest flood risk follows the fluvial corridors, particularly Patternden Farm Drain. Within Marden, the greatest flood risk is to the Wheelbarrow Estate and Howland Road.

### 5.1.1 Property count

Property counts were based on the results from the Integrated Urban Drainage Model as this was considered the best representation of flood risk in the catchment. The analysis was undertaken using Frism, a JBA GIS-based tool for analysing flood impact and damages. A detailed count was undertaken which utilises the Master Map building footprints in conjunction with the NRD property points. A property point is counted as flooded if its corresponding building footprint is within the flood outline, even if the property itself may not fall within the flood outline.

The total number of properties counted at each return period is shown in Table 5-1.

Table 5-1: Baseline property count at each Annual Exceedance Probability (AEP) event

| Flood Event Return Interval | Residential Properties Flooded | Non Residential Properties Flooded | Total |
|---|---|---|---|
| 50% AEP event | 31 | 27 | 58 |
| 10% AEP event | 60 | 79 | 139 |
| 5% AEP event | 70 | 94 | 164 |

| Flood Event Return Interval | Residential Properties Flooded | Non Residential Properties Flooded | Total |
|---|---|---|---|
| 3.33% AEP event | 83 | 100 | 183 |
| 2% AEP event | 89 | 116 | 205 |
| 1.33% AEP event | 94 | 132 | 226 |
| 1% AEP event | 98 | 138 | 236 |
| 0.1% AEP event | 137 | 206 | 343 |

The model results show that an increasing number of properties are flooded at each return period, as would be expected. The results suggest relatively few properties are at risk in a 50 % AEP event and the number of residential properties at risk is does not increase significantly between a 3.33 and 1 % AEP event. There are more non-residential properties at risk than residential properties. This shows how the less vulnerable land uses have been permitted in areas with greater probability of flooding. Non-residential properties predicted to flood are generally outside of the village, within the wider parish with exception of commercial buildings at Wheel Barrow Estate.

### 5.1.2 Damage calculation

Internal flooding of properties has an economic impact. The majority of financial cost is due to the damage incurred to the property (direct damages) but there are also secondary costs such as the emergency response (indirect damages) and the impact to health (intangible damages).

The damage calculation includes all of these costs. The Multi-Coloured Manual (MCM) 2013 provides a methodology for calculating damages, as well as cost versus flood depth curve which has informed this assessment.

A property threshold level of 0.15 metres has been assumed. This means that if a property is intersected by a flood depth less than 0.15m, it has been assumed that no direct damage will be incurred as the flood water could not access the property.

The damages curve for each of the properties was adjusted to account for inflation. This was done by using the monthly variation of the Customer Price Index (CPI) which was inputted at 132.6. The CPI uses the prices of a representative sample to statistically estimate the variation in the real property value whilst accounting for the changes in the rate of inflation.

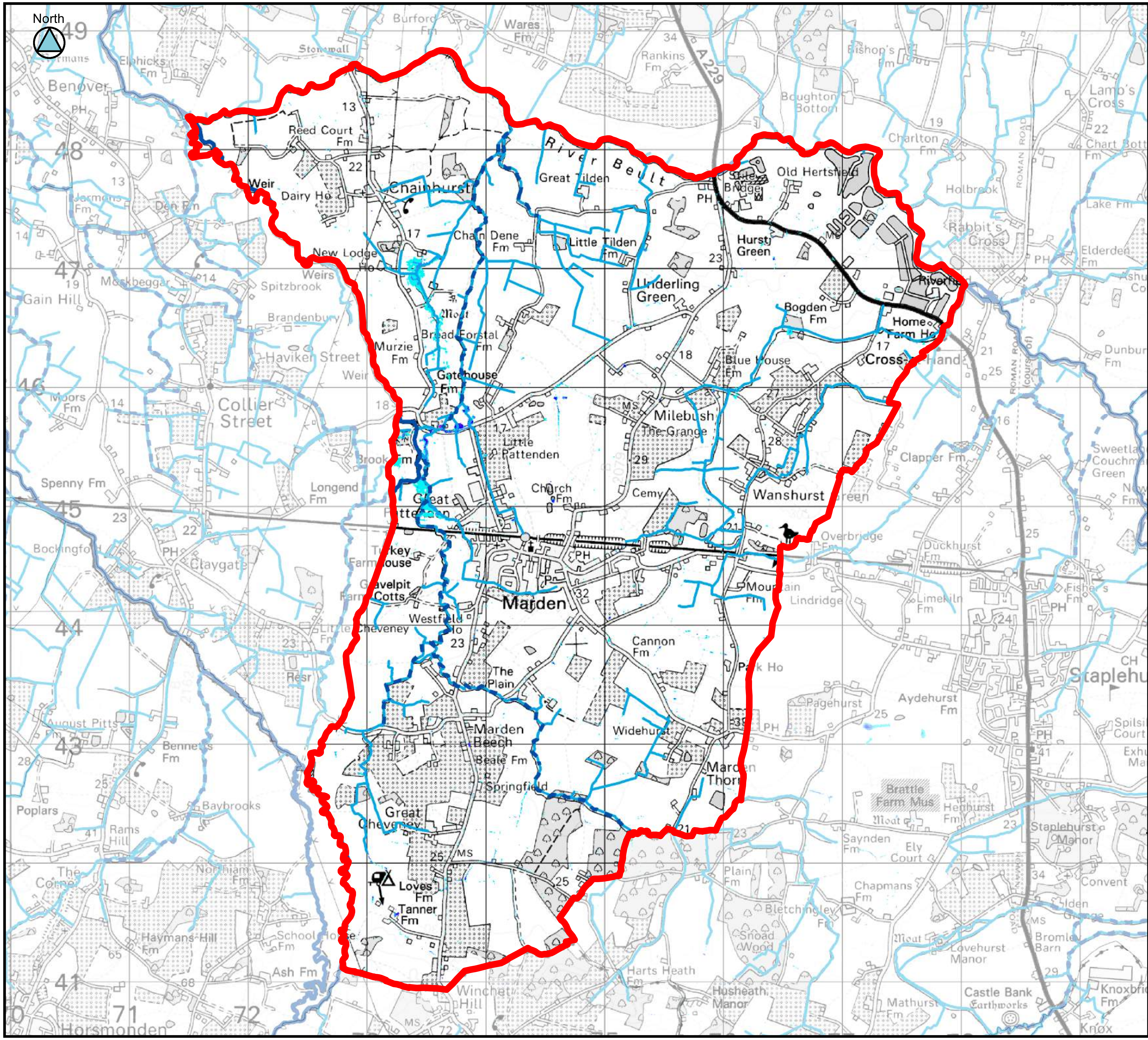
The economic damages estimated for the baseline scenario for each Annual Exceedance Probability (AEP) is shown in Table 5-2.

Table 5-2: Baseline damage calculation at each Annual Exceedance Probability (AEP) event to the nearest £k

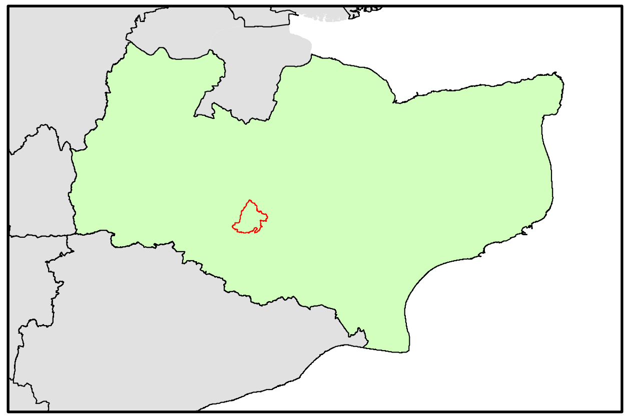
| Flood Event Return Interval | Residential (£) | Commercial (£) | Total Damage (£) |
|---|---|---|---|
| 50% AEP event | 332,000 | 2,694,000 | £3,026,000 |
| 10% AEP event | 689,000 | 3,628,000 | £4,317,000 |
| 5% AEP event | 886,000 | 3,846,000 | £4,732,000 |
| 3.33% AEP event | 985,000 | 4,133,000 | £5,118,000 |
| 2% AEP event | 1,132,000 | 4,352,000 | £5,484,000 |
| 1.33% AEP event | 1,286,000 | 4,799,000 | £6,085,000 |
| 1% AEP event | 1,363,000 | 4,985,000 | £6,348,000 |
| 0.1% AEP event | 2,153,000 | 4,982,000 | £7,135,000 |

At the lower return periods tested the commercial damages are calculated to be higher than the residential damages, despite the smaller number of properties to be at risk. This is because the commercial properties predicted to be a risk have a large floor plan and locally the flooding can be quite deep, despite not inundating the entire building. During the higher return period events, the residential damages become costlier than the commercial damages. This is due to the increasing number of properties predicted to be at risk.

# E Appendix E - Model Results




# Key Plan



# Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**50% AEP event**

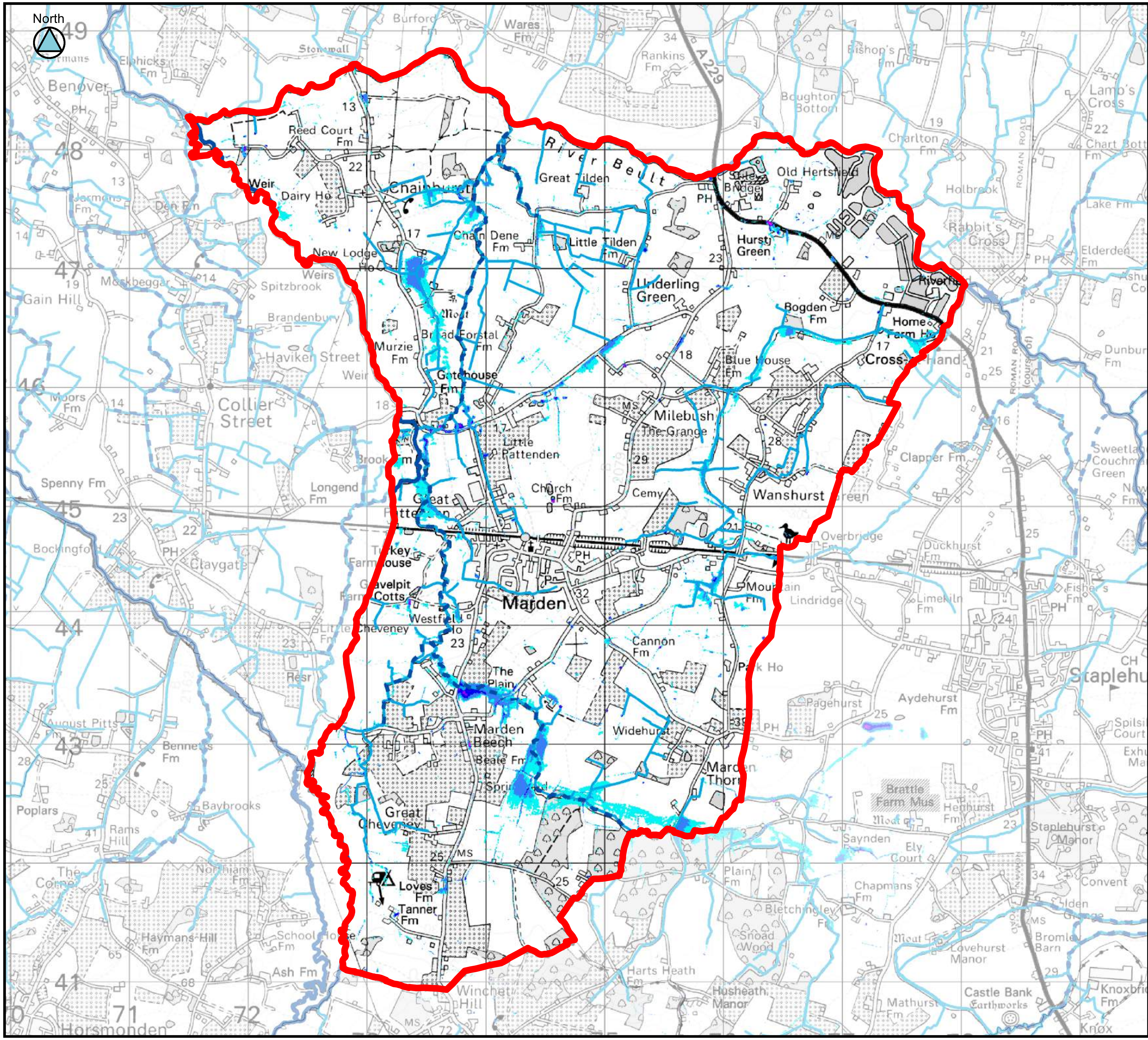
**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

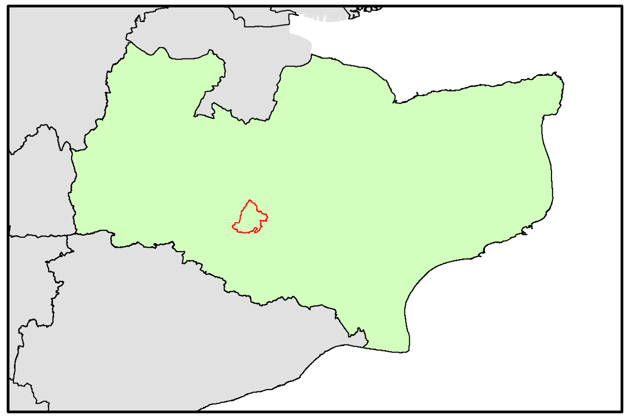
0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN




## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**10% AEP event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

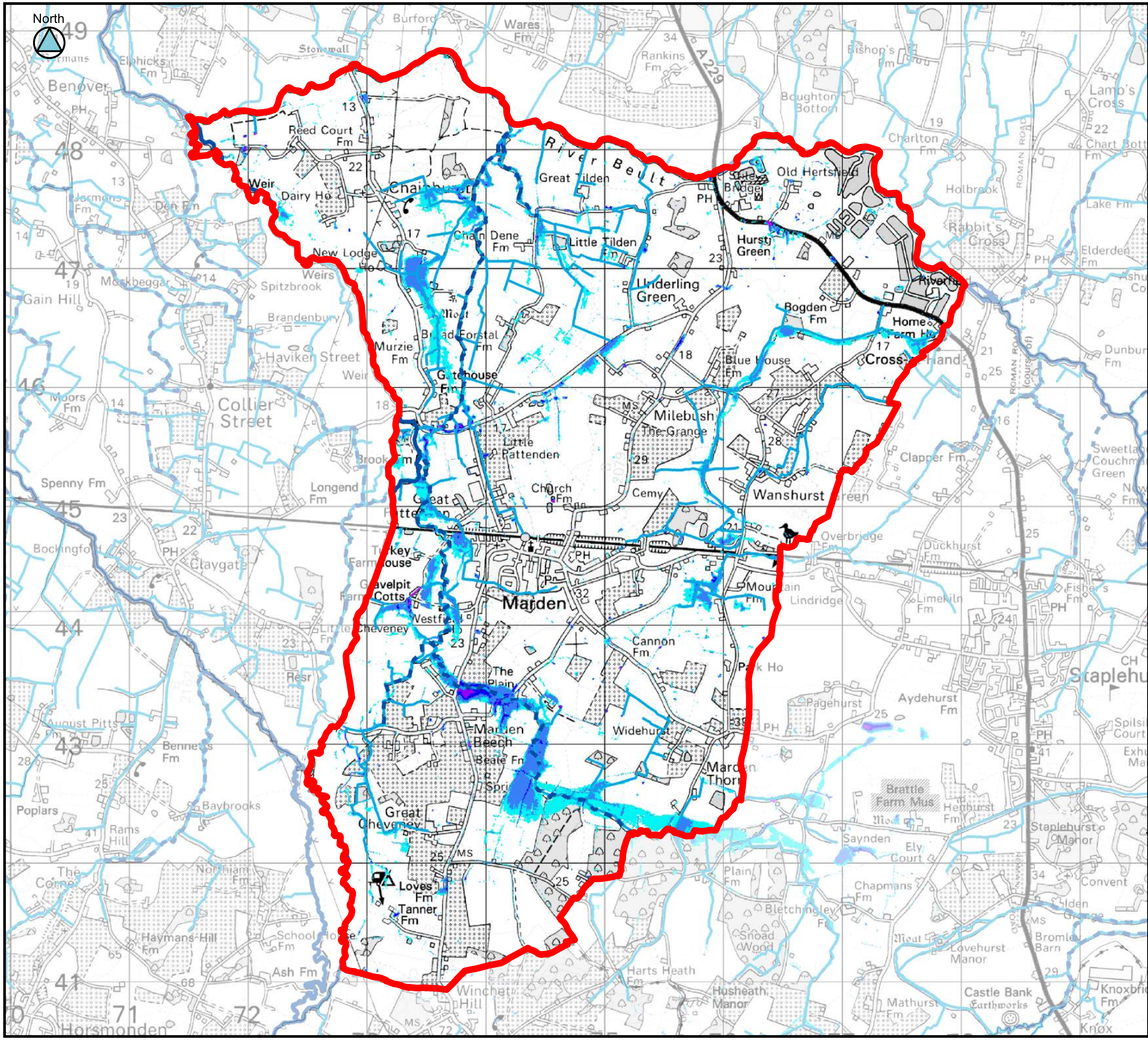
0 0.5 1 2 km

KENT COUNTY COUNCIL

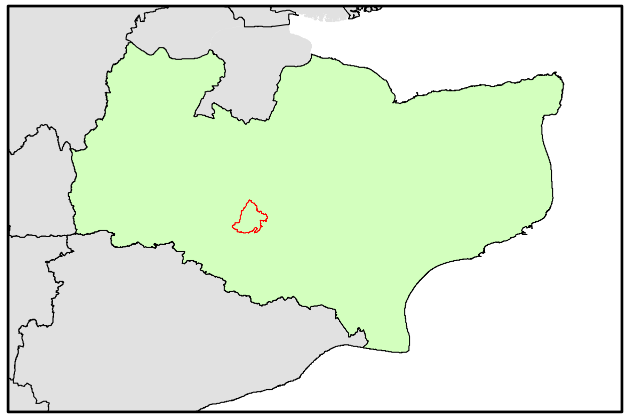
MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.




## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**5% AEP event**

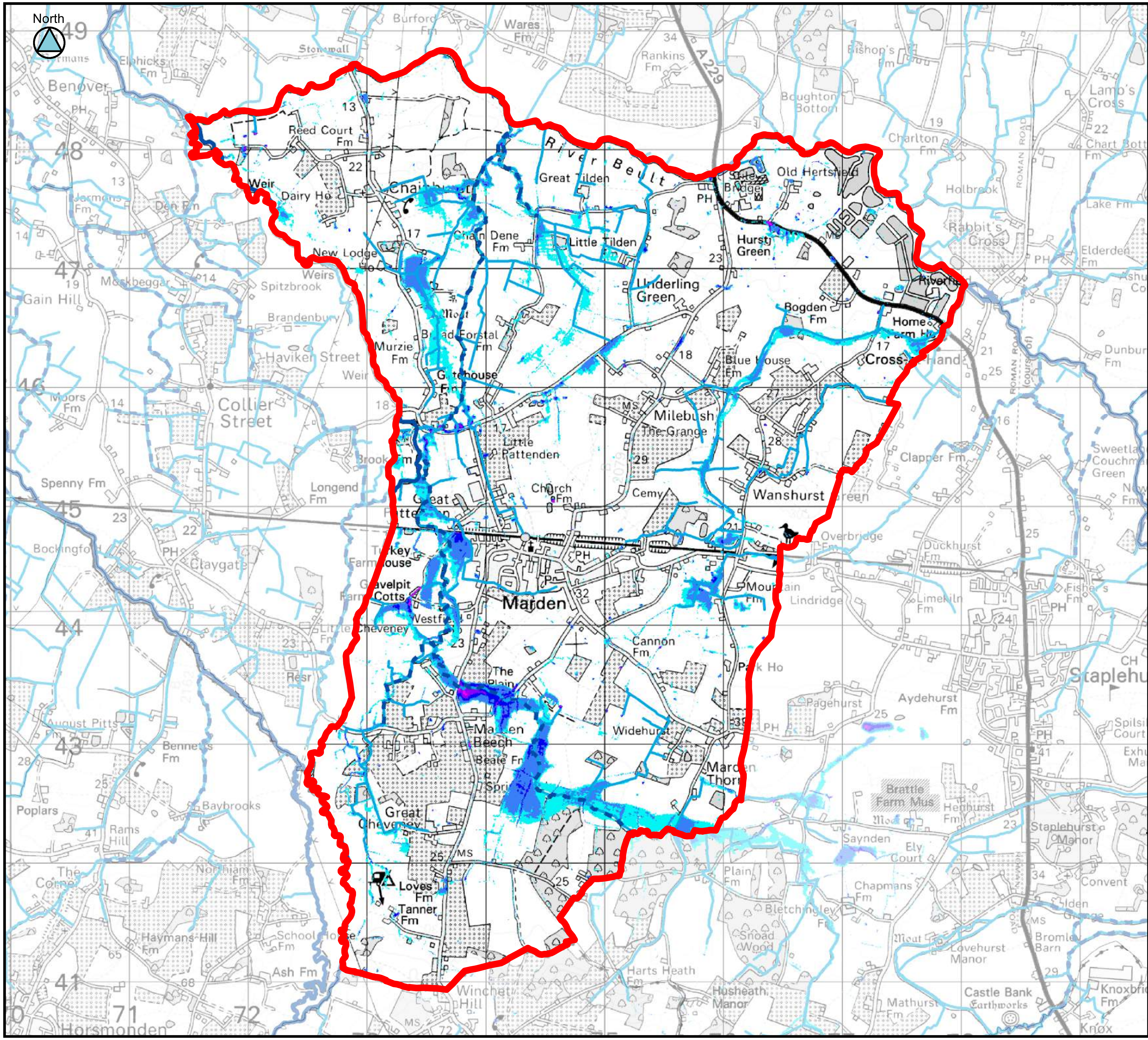
**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

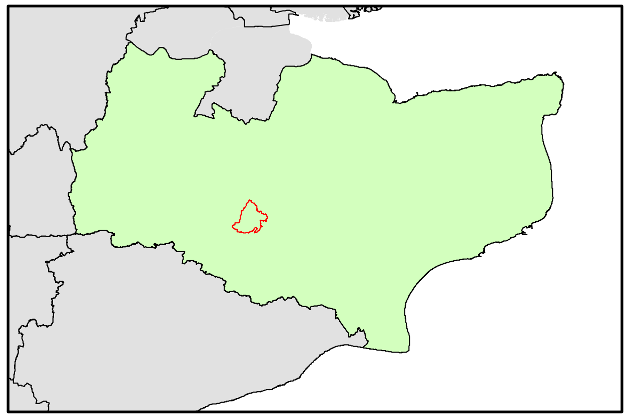
0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN




## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**3.33% AEP event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.



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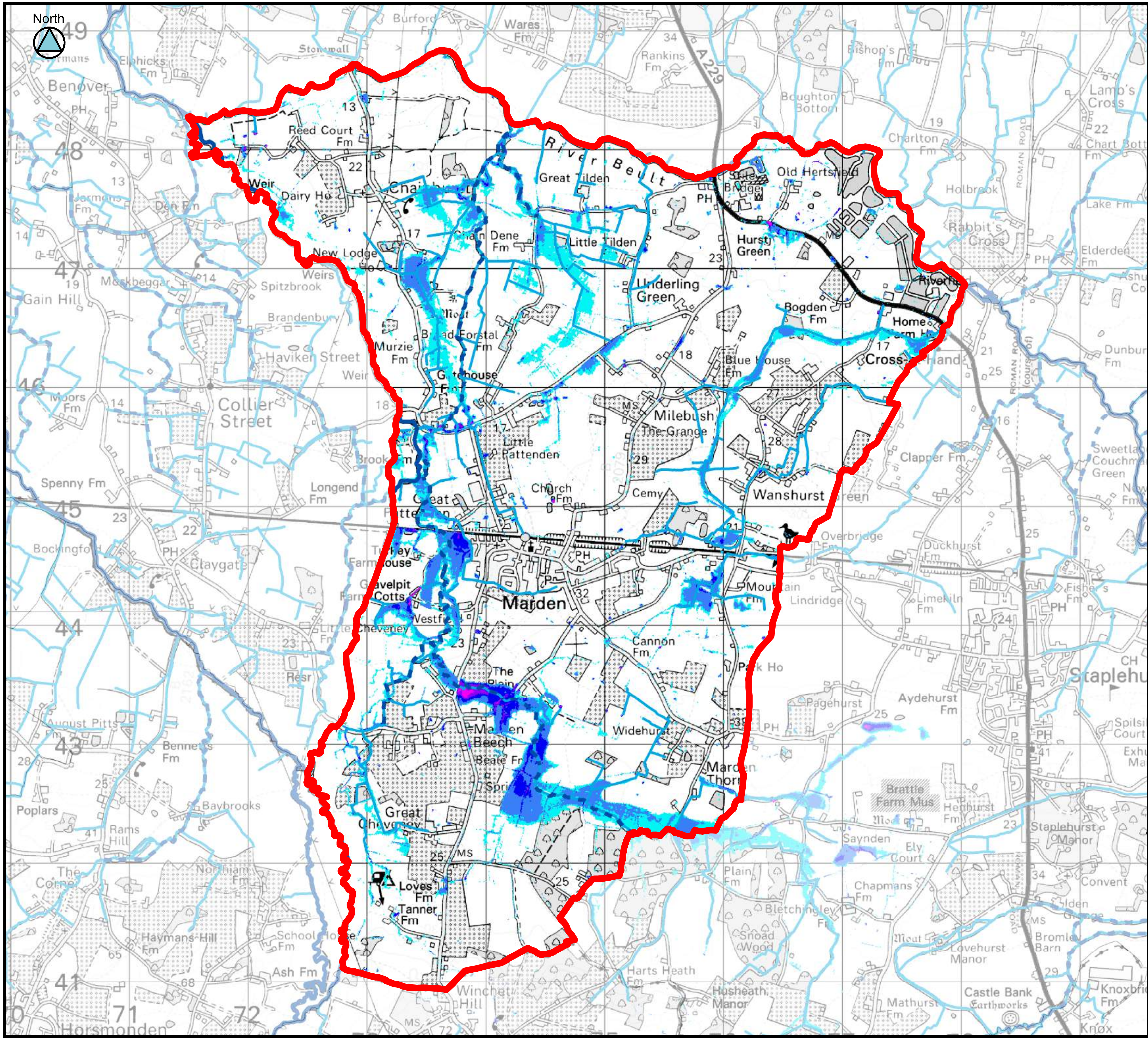
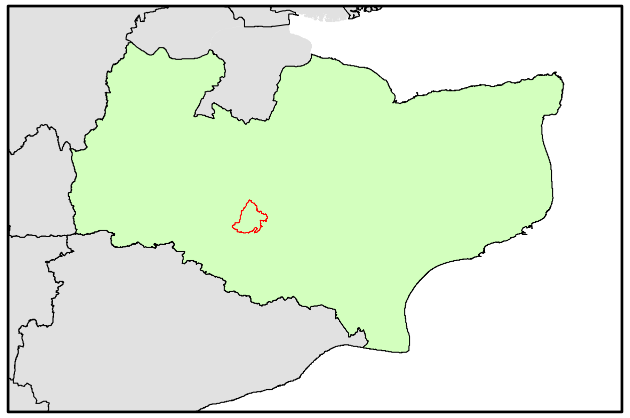



## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**2% AEP event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.



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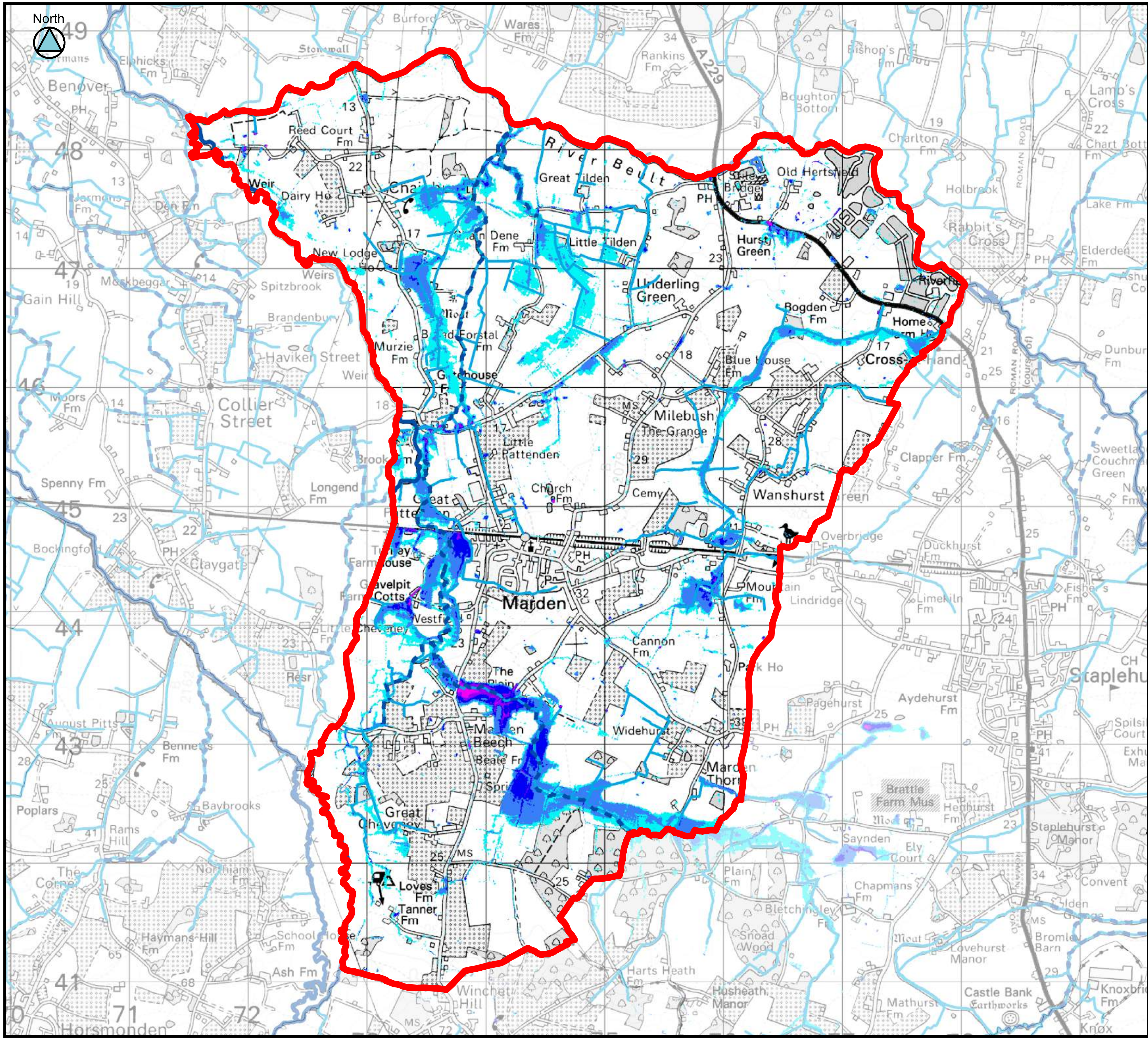
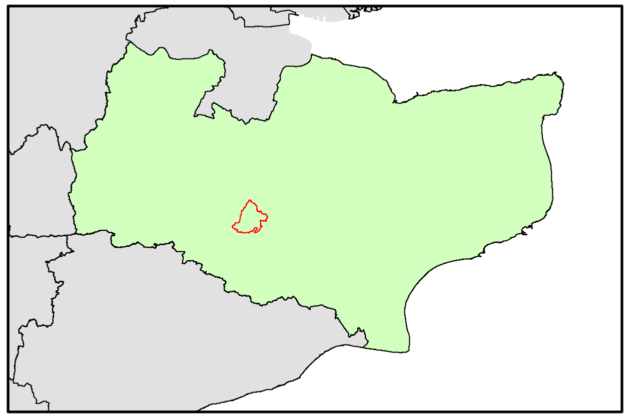



## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**1.33% AEP event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.



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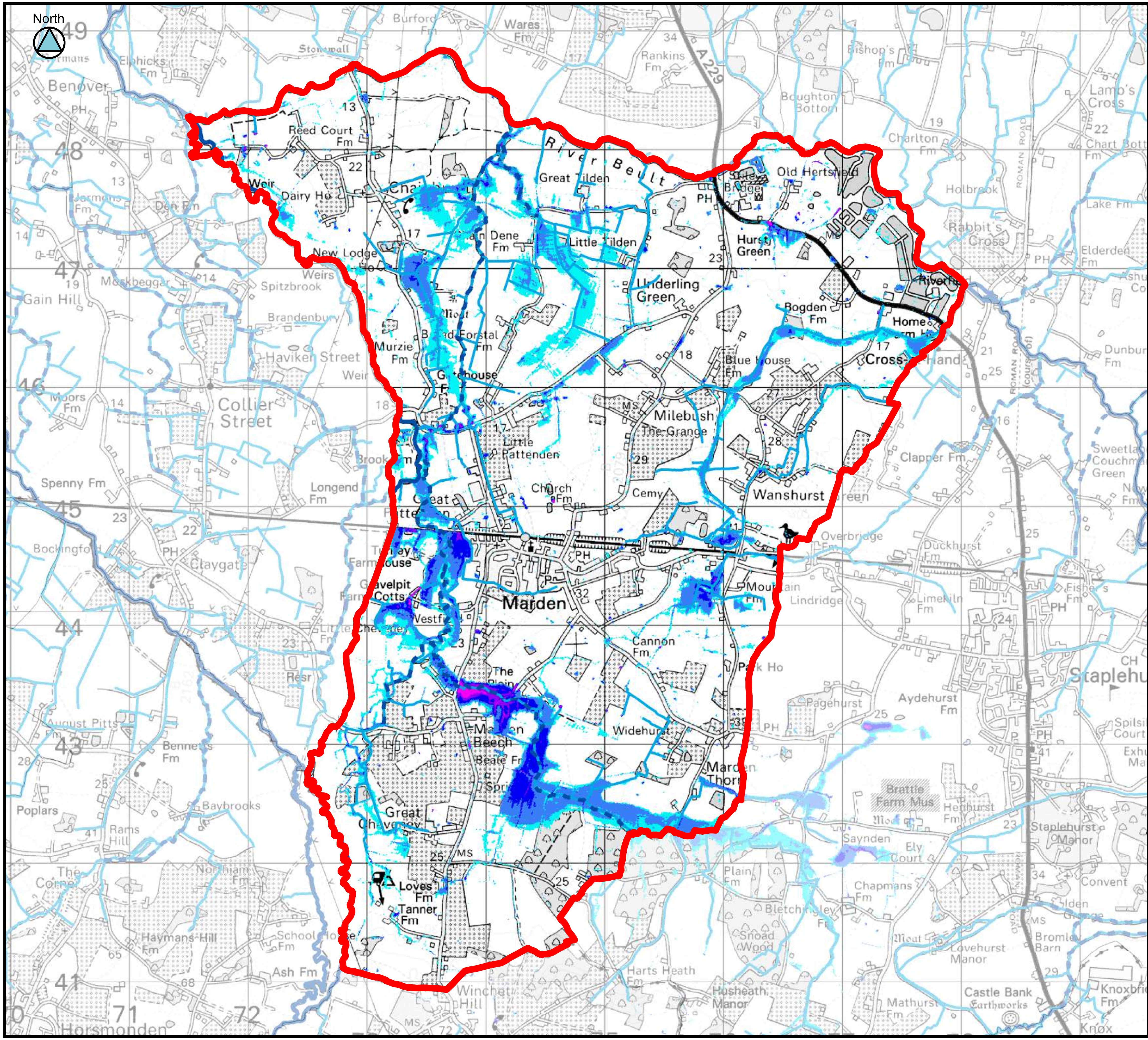
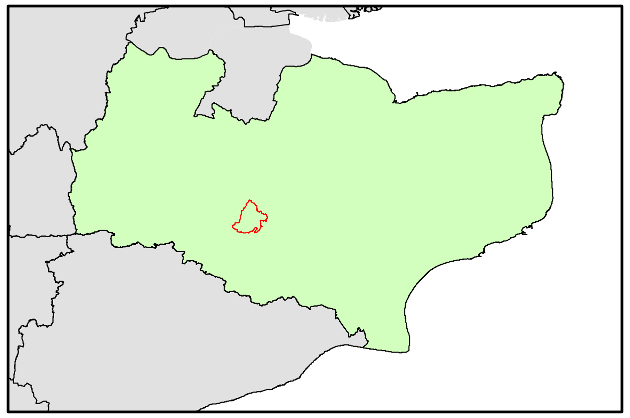



## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**1% AEP event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.



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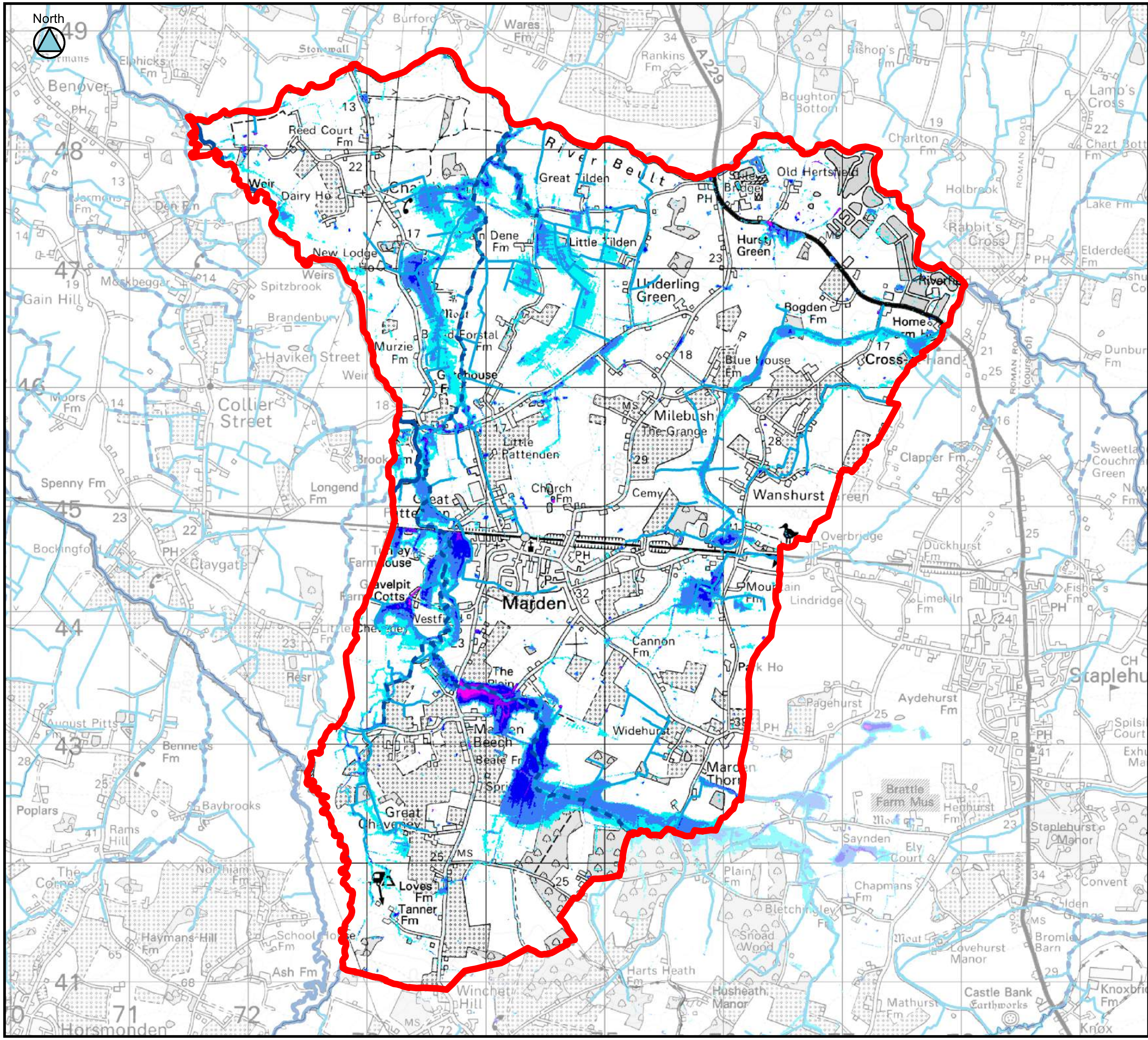
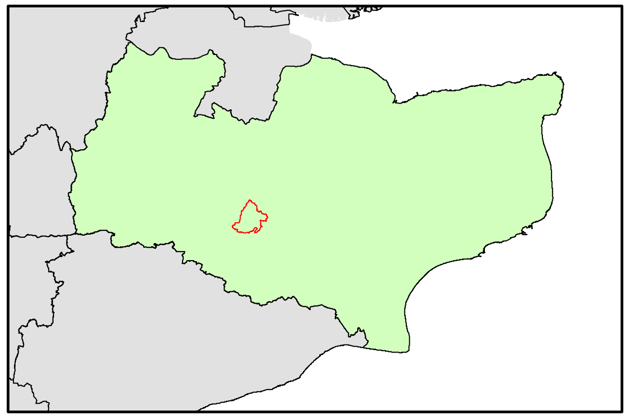



## Key Plan



## Legend

- Marden Parish
- Main River
- IDB Drain
- Ordinary Watercourse

**1% AEP + CC event**

**depth (m)**

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 5.00

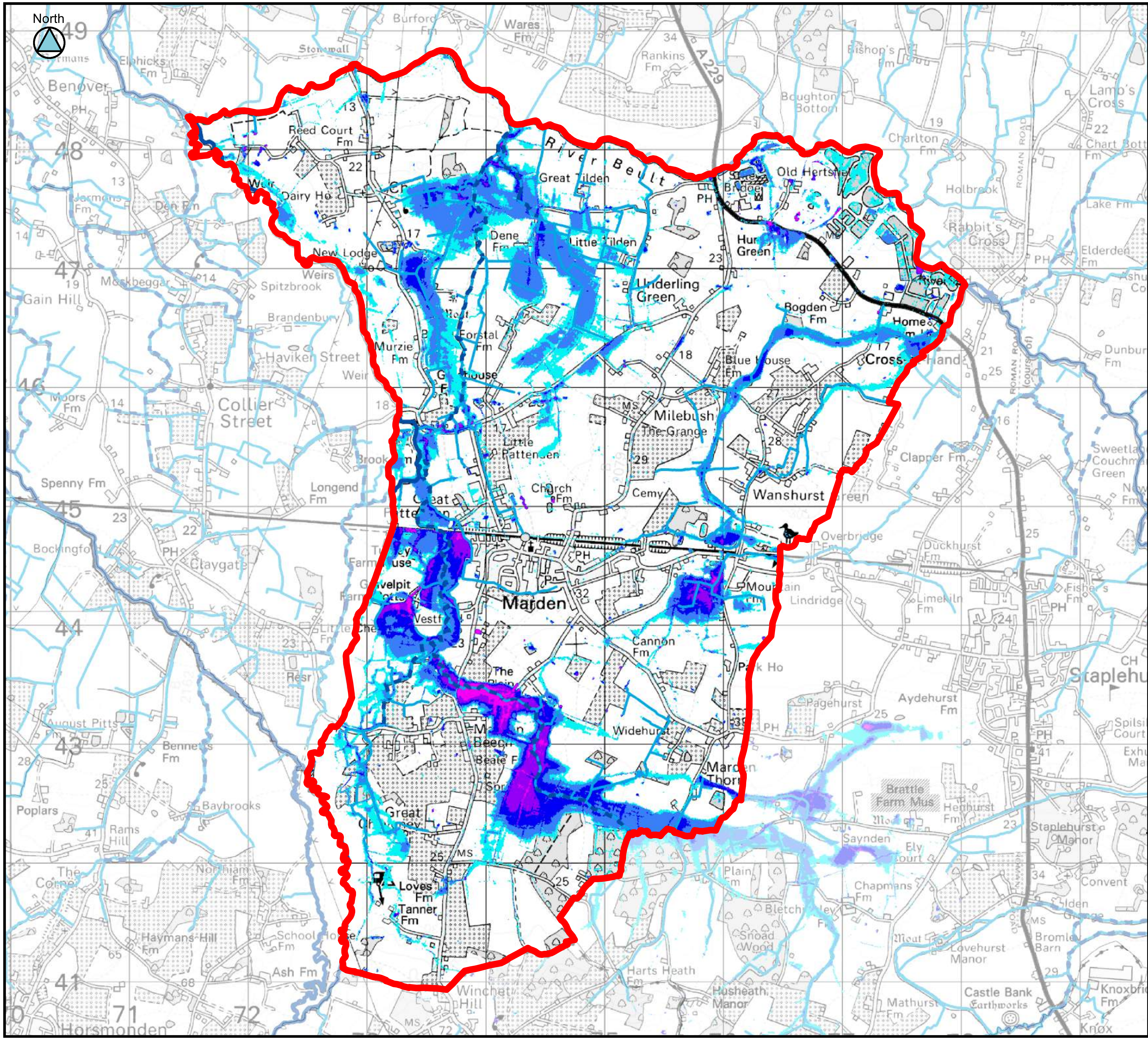
0 0.5 1 2 km

KENT COUNTY COUNCIL

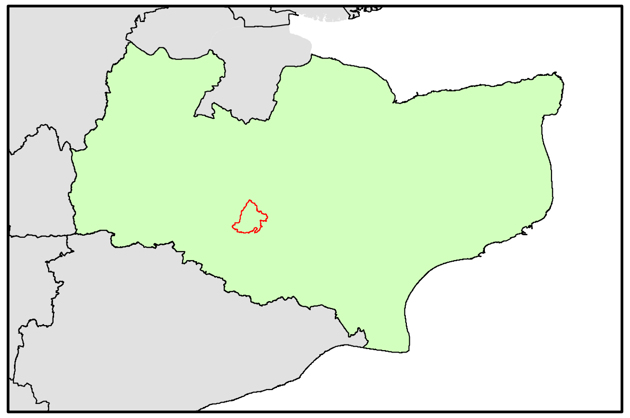
MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.




## Key Plan



## Legend

Marden Parish

Main River

IDB Drain

Ordinary Watercourse

**0.1% AEP event**

**depth (m)**

0.00 - 0.25

0.25 - 0.50

0.50 - 0.75

0.75 - 1.00

1.00 - 5.00

0 0.5 1 2 km

KENT COUNTY COUNCIL

MARDEN SURFACE WATER MANAGEMENT PLAN



Information regarding modelled and histprical flood risk is constantly changing. Users should consult the Environment Agency for the lastest flood risk information relating to specific planning applications.

# F Appendix F - Cost Benefit Analysis

# F Cost Benefit Analysis

This section discusses the economic appraisal carried out during this study. The methods of calculating the benefits and costs are outlined together with an assessment of the benefit-cost ratios for the flood storage options assessed.

Guidance on assessing the cost and benefits is provided in the Environment Agency's Flood and Coastal Erosion Risk Management - Appraisal Guidance[1] (FCERM-AG), supplemented by guidance and data from the following sources:

- The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques[2] (Multi-Coloured Manual or MCM);
- HM Treasury Green Book[3];
- Long Term Costing Tool[4]

Benefit-cost analysis looks at a flood risk management strategy or practice and compares all the benefits that will be gained by its implementation to all the costs that will be incurred during the lifetime of the project.

In accordance with the FCERM-AG, benefits are taken as annual average damages avoided, expressed as their present value using Treasury discount rates. These are compared with the whole life cost of the capital and maintenance costs of selected options, expressed as present value. If the benefits exceed the costs for the option, the scheme is deemed to be cost effective and worthwhile for promotion.

## F.1 Cost of proposed flood risk management options

Cost estimated were required for each of the options under consideration. The outputs and tool from the Long Term Costing project (SC080039) were used for the purpose of this assessment. This project was undertaken by JBA and provided a range of cost 'evidence summary' reports and a long term costing estimation tool. The tool allows users to derive a range of costs for a portfolio of flood defence measures and is ideally suited to strategic level studies.

Whole life costs are generated by the tool for 4 key cost categories:

1. *Preliminaries*. These costs relate to the mobilisation and for the purpose of this project it is assumed to be 15% of the construction cost. These do not include land purchase costs, and later stages of assessment should seek to understand if this will be required before scheme progression
2. *Construction works.* These costs relate to the construction of the flood mitigation measures and include relevant costs such as project management, construction and materials, licences, administration and supervision. This does not include landscaping.
3. *Construction contingency:* Contingency costs should be budgeted to allow for unforeseen costs. For the purpose of this project it is assumed to be 10% of the construction cost.
4. *Design fees.:* These costs relate to the cost for the next stage of the assessment, including detailed design of the flood mitigation measures. For the purpose of this project it is assumed to be 10% of the construction cost.
5. *Optimism bias*. As the flood mitigation measures outlined in this report are very high level, an optimism bias is appropriate to account for the uncertainties at this stage. The FCERM-AG recommends a value of 60% for projects in an early stage of consideration and therefore, for the purpose of this project it is assumed to be 60% of the construction cost.

The options considered for Marden include a number of surface water management measures. The costing consideration for each flood mitigation measure is outlined in Table F-1 below.

1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/481768/LIT_4909.pdf
2 Penning-Rowsell, *et al* (2013) The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques
3 HM Treasury (2011) The Green Book, Appraisal and Evaluation in Central Government.
4 Environment Agency and Defra (2015) Long term costing tool for flood and coastal risk management.

Table F-1: Indicative costs for typical flood mitigation measures

| Option | Unit cost | | Source |
|---|---|---|---|
| Wall | Height (m) | Cost (£/m) | Environment Agency Unit Cost Database (average length in database = 180 m) |
| | <1.2 | 1,419 | |
| | 1.2 - 2.1 | 2,905 | |
| | 2.1 - 5.3 | 3,577 | |
| | >5.3 | 11,168, | |
| | All heights | 2,984 | |
| Embankment | Volume band ($m^3$) | Cost (£/$m^3$) | Environment Agency Unit Cost Database (average volume per meter length = 18$m^3$) |
| | <500 | 188 | |
| | 500 - 5,000 | 94 | |
| | 5,000 - 15,000 | 64 | |
| | >15,000 | 33 | |
| Swales | £10-£15 per $m^2$ swale area<br>£18-£20 per m length using an excavator<br>£12.5 per $m^2$ | | CIRIA, 2007<br>Stovin & Swan 2007<br>Environment Agency, 2007 |
| Infiltration basin | £10-£15 per $m^3$ stored volume | | CIRIA, 2007 |

The upper end costing has been used in all cases after advice from Kent County Council that overall costing was lower than expected based on the costs of schemes delivered in Kent.

### F.1.1 Cost summary

A summary of the scheme costs is presented in the below. The costs present related only to scheme costs.

Table F-2: Details of the option model and associated scheme costs (£k)

| Option | Preliminaries | Construction | Contingency | Design fees | Optimism bias |
|---|---|---|---|---|---|
| 1 - The Cockpit | 1 | 7 | 1 | 1 | 4 |
| 2 - Plain Road | 113 | 754 | 75 | 75 | 452 |
| 3 - Howland Road | 11 | 75 | 8 | 8 | 45 |
| 4 - Wheelbarrow Estate | 3 | 17 | 2 | 2 | 10 |

## F.2 Benefit assessment for floor risk management options

Benefits are assessed as the flood damages that will be avoided by the implementation of a project. Property counts and damage estimates have been calculated using Frism, JBA's in-house flood metrics software.

### F.2.2 Baseline scenario

To calculate the benefits or a proposed scheme, it is necessary to assess the damages that are likely to occur under a baseline scenario, which represents the scenario in which no flood defence works are carried out. The baseline scenario assumes the current maintenance regime would continue. This would include periodic channel maintenance, removal of debris, maintenance and repair of assets but no new structures would be constructed or capital expenditure invested.

### F.2.3 Options

Four flood risk management options were identified and taken forward for cost-benefit assessment. The economic appraisal was carried out for each of the options in isolation to understand the individual contribution.

### F.2.4 Present value

Benefits have been calculated throughout the project life which is assumed to be 100 years. All benefits and costs have been assessed at a price base date of October 2015 with future benefits and costs being discounted to present value using a varying treasury discount rate. This is in line with Defra guidance4.

The MCM data is based on January 2013 prices, and was therefore brought up to date in order to more accurately compare the costs and benefits. The FCERM-AG recommends that this is carried out using the consumer price index (CPI). The current and January 2013 indices for the CPI are provided in Table 7-3. The MCM damages estimates have been factored against the current CPI in order to bring them up to present day prices representing an increase in damages of approximately 3%.

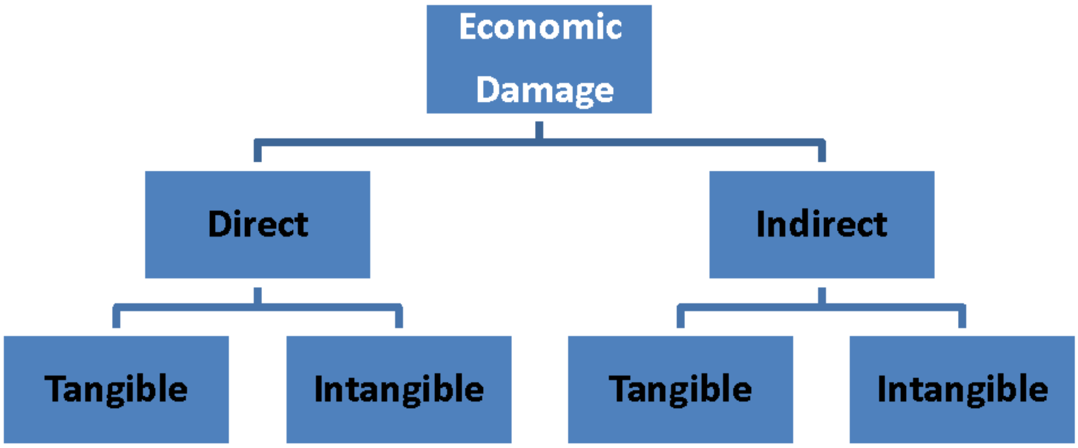
Table F-3: CPI adjustment factors (£k)

| January 2013 | October 2015 | Adjustment factor |
|---|---|---|
| 124.4 | 128.2 | 1.03 |

### F.2.5 Methodology

Flood damage assessment can include direct, indirect, tangible and intangible aspects of flooding, as shown in Figure F-1 below. Direct damages are the most significant in monetary terms, although the MCM and additional research provide additional methodologies, recommendations and estimates to account for the indirect and intangible aspects of flood damage.

Figure F-1: Aspects of flood damage




Flood damage estimates have been derived for the following items:

- Direct damages to residential properties;
- Direct damages to commercial and industrial properties;
- Indirect damages (emergency services);
- Vehicle damages.
- Intangible damages associated with the impact of flooding;

The assumptions and additional data recorded below were used to improve and provide the necessary information to supplement the above datasets.

#### Data and assumptions

The Multi-Coloured Manual provides standard flood depth/direct damage datasets for a range of property types, both residential and commercial. This standard depth/damage data for direct and indirect damages has been utilised in this study to assess the potential damages that could occur under each of the options. Flood depths within each property have been calculated from the 2D hydraulic modelling by comparing predicted water depths at each property to the ground level implemented with the hydraulic model, which are informed from filtered LIDAR data.

A mean, minimum and maximum flood depth within each property footprint is derived by JBA's in-house FRISM tool. Only the mean flood damages have been presented. A key assumption with the flood damage calculations is that a given property threshold levels is present across all properties.

An assumed threshold value of 150mm (property thresholds assumed to be 150mm above the model ground levels) was assumed across the study area. Clearly such an assumption can have large implications on the damages predicted within the study area and more detailed assessment into FRM options should seek to better understand threshold levels within the study area, and ideally have property threshold levels surveyed which would provide much greater clarity on predicted flood depths within properties.

The assumptions presented in were used to generate direct flood damage estimates.

Table F-4: Direct flood damage assumptions

| Data type | Data and any assumptions used |
|---|---|
| Depth damage data | Multi-Coloured Manual used |
| Flood depths | Mean flood depths for each property extracted for:<br>50%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, and 0.1% AEP events |
| Threshold level | No threshold values surveyed. 150mm above modelled ground levels adopted across the study area. |
| Residential property types | Defined by property types (Detached, Semi-Detached, Terraced, Flat, Bungalow). |
| Upper floor flats | Upper floor flats have been removed from the flood damage estimates. Whilst homeowners may be affected it is assumed that no direct flood damages are applicable. |
| Non-residential property types | MCM property types defined using national receptor dataset. |
| Property areas | Defined by OS MasterMap data. |
| Capping of property damages | Property market values have not been used for capping. Capping has not been completed. |
| Updating of MCM damage data | Consumer Price Index to October 2015 used. |

### Errors and limitations

The approach to estimation of flood damages assumed the mean flood depth is applicable across the entire building footprint. This is not always true, particularly where localised surface water ponding is predicted. Within large property boundaries this can significantly over estimate the likely damages and is most noticeable in the non-residential results as it particularly impacts warehouse buildings with large footprints. A more thorough analysis using surveyed threshold levels would help to correct these inconsistencies in the future.

### Indirect damages

The Multi Coloured Manual provides guidance on the assessment of indirect damages. It recommends that a value equal to 5.6% of the direct property damages is used to represent emergency costs and have been accounted for in the Frism outputs. These include the response and recovery costs incurred by organisations such as the emergency services, local authorities and the Environment Agency.

Guidance and standard costs are also provided in the Multi-Coloured Manual for the assessment of additional costs incurred by property owners as a result of flooding. These include rental costs for alternative accommodation, additional heating and electricity costs required to dry out a flooded property. These have not been included in the analysis at this stage.

### Intangibles

Current guidance indicates that the value of avoiding health impacts of fluvial flooding is of the order of £290 per year per household. This value is equivalent to the reduction in damages associated with moving from a Baseline scenario to an option with an annual flood probability of 1% (100-year standard).

### Vehicular damages

The Multi Coloured Manual provides guidance on the assessment of vehicular damages. It is recommended for project appraisals to use an average loss value of £3,600 per residential property in the risk area. This is accounted for flood depth greater than 0.35m above bare ground levels (not above property threshold level) at each property.

## F.2.6 Baseline flood damage results

The number of properties (residential and non-residential) flooded in the design events simulated is summarised in Table F-5.

Table F-5: Counts of ground floor residential and non-residential properties intersect the predicted flood extent (baseline case)

| Flood Event Return Interval | Residential Properties Flooded | Non Residential Properties Flooded |
|---|---|---|
| 50% AEP event | 31 | 27 |
| 10% AEP event | 60 | 79 |
| 5% AEP event | 70 | 94 |
| 3.33% AEP event | 83 | 100 |
| 2% AEP event | 89 | 116 |
| 1.33% AEP event | 94 | 132 |
| 1% AEP event | 98 | 138 |
| 0.1% AEP event | 137 | 206 |

The damages predicted at each design event simulated are summarised in Table F-6. These account for direct and indirect damages, including emergency cost and vehicular damages.

Table F-6: Damages of residential and non-residential properties

| Flood Event Return Interval | Residential (£) | Commercial (£) |
|---|---|---|
| 50% AEP event | 332,000 | 2,694,000 |
| 10% AEP event | 689,000 | 3,628,000 |
| 5% AEP event | 886,000 | 3,846,000 |
| 3.33% AEP event | 985,000 | 4,133,000 |
| 2% AEP event | 1,132,000 | 4,352,000 |
| 1.33% AEP event | 1,286,000 | 4,799,000 |
| 1% AEP event | 1,363,000 | 4,985,000 |
| 0.1% AEP event | 2,153,000 | 4,982,000 |

## F.2.7 Option flood damage results

To assess the impact of the options, the damages for the baseline and options were calculated using a reporting unit just covering the area of impact. The estimated damages (residential and non-residential) flooded in the design events simulated is summarised in Tables F7- F10.

Table F-7: Damages of ground floor residential and non-residential properties in the Cockpit (£k)

| AEP event | Residential properties at risk | | Non-residential properties at risk | |
|---|---|---|---|---|
| | Base | Option | Base | Option |
| 10 | 15 | 0 | 0 | 0 |
| 2 | 20 | 11 | 0 | 0 |
| 1 | 23 | 12 | 0 | 0 |

Table F-8: Damages of ground floor residential and non-residential properties in Plain Road(£k)

| AEP event | Residential properties at risk | | Non-residential properties at risk | |
|---|---|---|---|---|
| | Base | Option | Base | Option |
| 10 | 9 | 9 | 0 | 0 |
| 2 | 13 | 11 | 0 | 0 |
| 1 | 15 | 12 | 0 | 0 |

Table F-9: Damages of ground floor residential and non-residential properties in Howland Road (£k)

| AEP event | Residential properties at risk | | Non-residential properties at risk | |
|---|---|---|---|---|
| | Base | Option | Base | Option |
| 10 | 7 | 0 | 0 | 0 |
| 2 | 8 | 7 | 0 | 0 |
| 1 | 9 | 8 | 0 | 0 |

Table F-10: Damages of ground floor residential and non-residential properties in Wheelbarrow Estate (£k)

| AEP event | Residential properties at risk | | Non-residential properties at risk | |
|---|---|---|---|---|
| | Base | Option | Base | Option |
| 10 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 8 | 2 |
| 1 | 0 | 0 | 12 | 10 |

## F.3 Benefit-cost results

The benefit-cost ratio compares the benefits of each option to the costs of that option and can be used to compare different engineering options.

### F.3.8 Option 1: The Cockpit

The results showed that an infiltration basin at the Cockpit is an affective measure to trap overland flows and prevent £11,000 of damages to residential properties. However, the cost of an infiltration basin was over twice as high as the benefits predicted to be brought about. During the options workshop KCC raised concerns that an infiltration basin in this impermeable catchment is likely to take a long time to drain down and would reduce the amenity value of the green space. As a result, a positively drained solution was sought. However, there was no option to discharge directly to the Cockpit Drain due to the location of housing and Southern Water and KCC highways do not take land drainage. Therefore, it is considered that this option is neither cost beneficial or practicable at this time.

### F.3.9 Option 2: Plain Road

Options were tested to retain access to Marden via The Plain during a 1% AEP event. The testing concluded that if the highway remained at the present level, the storage required to maintain access would be impractically large. Therefore, storage was considered in combination with highway raising. The construction of a raised highway embankment is hugely expensive but no benefit was predicted to properties at risk. As a result, the costs outweighed the benefits at a ratio of 135:1. Therefore this option is not cost beneficial. In addition, access to Marden can be achieved via alternative routes. Therefore, the closure of The Plain is an inconvenience rather than a health and safety risk to residents.

### F.3.10 Option 3: Howland Road

The option appraisal of Howland Road found the most affective opportunity to manage surface water was to combine the swale behind properties and the attenuation basin upstream of the railway culvert. However, the predicted flood damages were only reduced from £9,000 to £8,000 under this option because rainfall continued to pond directly on properties. As a result, the estimated costs of the SuDS outweighed the flood damage benefits at 52:1. Therefore this option is not cost beneficial. However, the swale and attenuation basin SuDS features should be considered as part of the drainage design if the Howland Road development progresses.

### F.3.11 Option 4: Wheelbarrow

Under the current conditions £14,000 of flood damages was predicted during a 1% AEP rainfall event at the Wheelbarrow Estate. This is reduced to £10,000 if an exceedance route is implemented. However, the estimated cost is lowering the private road is three times greater than the predicted benefits. Therefore, this option is not cost beneficial. In addition, these properties are predicted to flood from the Lesser Teise at a 20% AEP fluvial event, and an exceedance route would not protect these properties from this flood risk. As a result, the exceedance route is not a sustainable use of public resources as the properties would remain at frequent flood risk.

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